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A CRETACEOUS GRIT BED HORIZON IN THE DISTRICTS WEST AND SOUTH FROM TURNER VALLEY, ALBERTA.

F. G. FOX
1942

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A CRETACEOUS GRIT BED HORIZON IN THE DISTRICTS WEST AND SOUTH FROM TURNER VALLEY, ALBERTA.

by

Frederick Glenn Fox, B. Sc.

Department of Geology

UNIVERSITY OF ALBERTA

A Thesis
Submitted to the University of Alberta
in partial fulfilment of the
requirements for the degree

of

MASTER OF SCIENCE

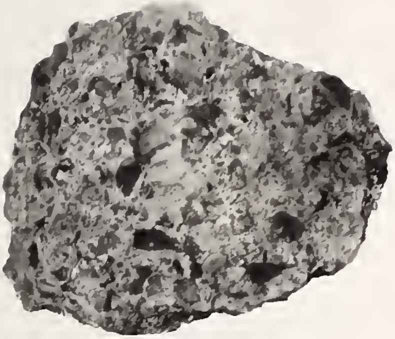
Edmonton, Alberta April 1942.

FRONTISPIECE

Coarse upper phase of the grit.

Coarse upper phase of the grit.

Fine grained lower phase of the grit.



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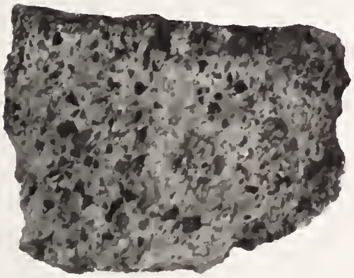

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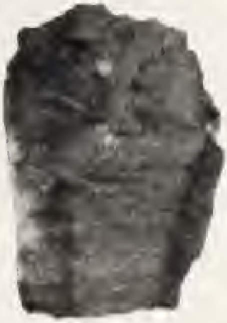

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Thesis
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TABLE OF CONTENTS

INTRODUCTION

Page
The Problem 1
Cretaceous Stratigraphy 1
Distribution of the Grit 3
Previous Studies 4
Present Study 5
Acknowledgements 7
Summary and Conclusions 8

LITHOLOGY AND PETROGRAPHY

General Statement 10
Lithology of the Grit 11
  General Description 14
  Descriptions of Sections Studied 14
    AREA 1 14
    AREA 2 15
    AREA 3 16
    AREA 4 17
    AREA 5 18
    AREA 6 19
    AREA 7 20
    AREA 8 21
    ADDITIONAL AREA 22
Correlation 23
Petrography of the Grit 25
  Essential Constituents 26
  Minor Constituents 28
  Authigenic Constituents 29
Classification of the Grit 30
Thin Section Descriptions 31

THEORETICAL CONSIDERATIONS

Page
Cretaceous History 55
Source of the Sediments 57
Production of the Sediments 62
Transportation of the Sediments 63
The Environment of Deposition 65
Conclusions Regarding Source, Transportation, and Deposition 70

BIBLIOGRAPHY

INDEX TO MAPS, PLATES, AND FIGURES

Map I (Map of Thesis Area) .... Inside back cover.

Plate I (Hand Specimens of the Grit) ... Frontispiece.
Plate II (Index Map of Alberta) .... After page . 3
Plate III (Photomicrographs of Thin Sections) .... " " 54

Figure 1. (Sketch of the Grit Bed) .... " " 12
Figure 2. (Columnar Sections of the Grit Bed) .... " " 22
Figure 3. (Hypothetical Profile Sections) " " 67

INTRODUCTION

The Problem

This thesis embodies the results of a study of a thin but rather persistent horizon in the Cretaceous strata in some parts of the foothills of southwestern Alberta. This horizon is known as the "Grit", or "Grit-bed", and in the past ten years it has been much used in the geological mapping of the foothills. It has generally been regarded as marking the approximate contact between the Lower Alberta Shale and the Blairmore formation, which are of Cretaceous age.

No detailed petrographic study of the grit has previously been made, and the question of its genesis and significance has not been satisfactorily determined. It was suggested that a systematic study of the grit might prove of worth to those engaged in structural and stratigraphic work in the foothills, as well as providing the writer with an excellent thesis problem. Accordingly, such an investigation was carried out.

The main object of this investigation has been to determine the composition and genesis of the grit, and its stratigraphic position. From this information inferences have been drawn as to its provenance, transportation, and deposition.

Cretaceous Stratigraphy

Since frequent reference is made to certain Cretaceous sediments in the foothills, a table, with brief notes on the

lithology, of the Cretaceous formations in the foothills of southern Alberta is here included.

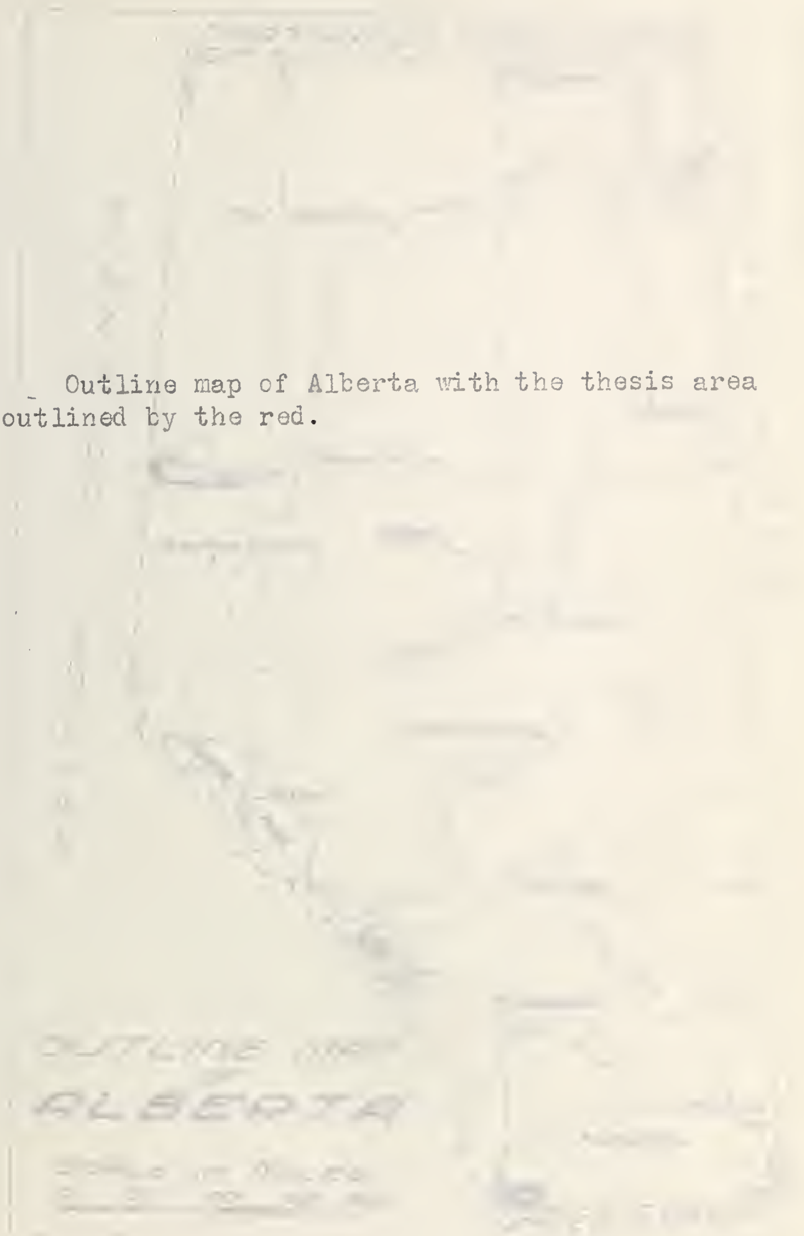
Upper Cretaceous	St. Mary River (Edmonton)		Continental. Light gray calcareous sandstones inter-bedded with shale. A few thin coal seams and oyster beds in the lower part. Montana in age.
	Bearpaw		Marine. Dark gray shales and sandy shales. Found only in the eastern foothills. Montana in age.
	Belly River		Continental. Light gray crossbedded sandstones inter-bedded with gray and sometimes greenish shales. Thin but non-persistant coal seams near the top. Fossils occur mainly near the base in thin limey bands. Montana in age.
	Alberta Shale	Upper Member.	Marine. Dark gray to black shales, thinly laminated, nodular in the middle part. Inocerami and Scaphites are common fossils. Colorado mainly, Montana in uppermost part.
		Cardium	Marine and brackish water. Brown weathering sandstone and conglomerate, gray shale. Cardium pauperculum common in some places, but fossils generally not abundant.
		Lower Member.	Marine. Black thinly laminated shales, increasingly sandy near the base. Inoceramus labiatus in the lower part. The grit occurs in the lower 65 feet, usually in the lower 25 feet. Colorado in age.

	Crowsnest Volcanics	Largely Subaqueous. Tuff, breccia, flow rocks, agglomerate.
Lower Cretaceous	Blairmore	Continental. Sandstones, shales and conglomerates. The formation is greenish as a whole. Red beds usually occur near the top. Massive conglomerate at the base Plant remains common in some areas.
	Kootenay	Continental. Gray sandstones and shales, often weather rusty color. Coal is common in upper part, plant remains usually present.

Distribution of the Grit

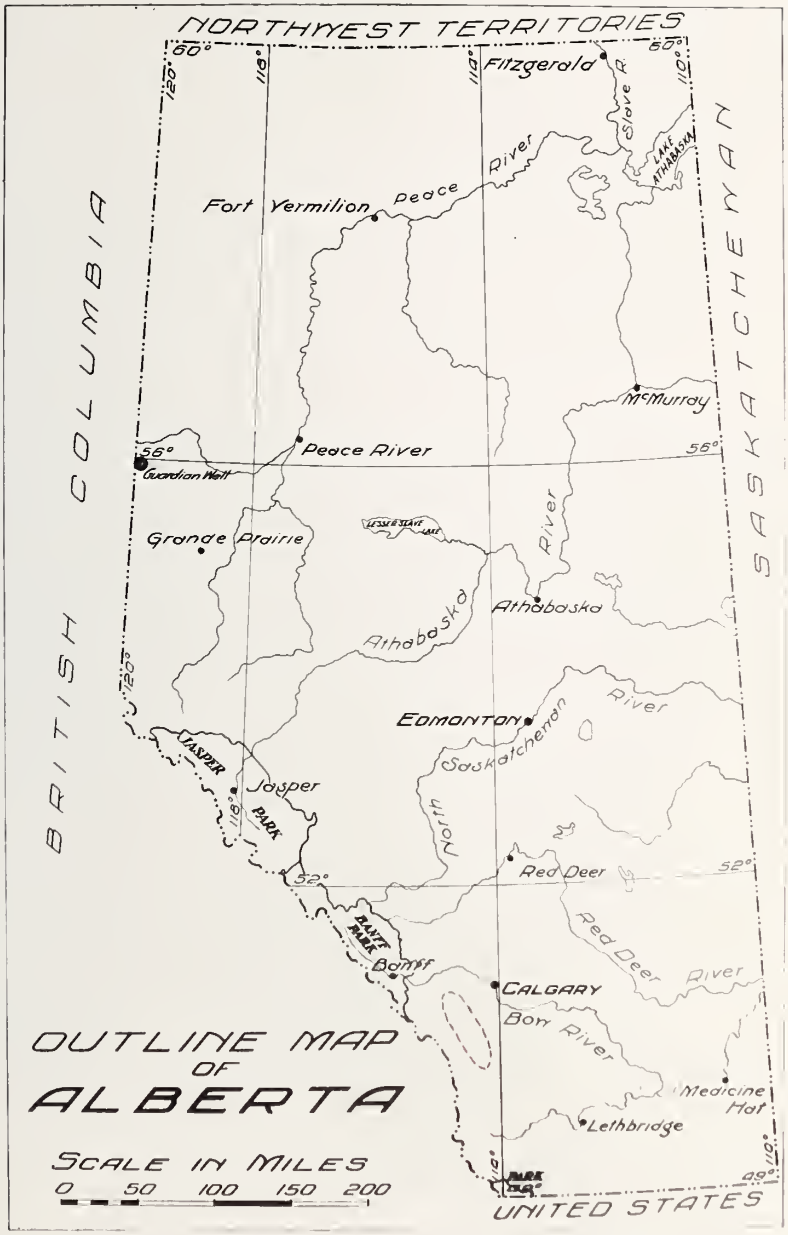
The grit is exposed only in the foothills of southwestern Alberta. The most southerly exposure of grit known to the writer is in Sec. 17, Tp. 13, Range 2, W 5th Mer., near the south fork of Willow Creek. In 1931 Dr. J.A. Allan and Dr. R.L. Rutherford collected specimens of a coarse chert conglomerate from near the base of the Alberta Shale in Lsd. 4, Sec. 7, Tp. 6, Range 1, W 5th Mer., on Mill Creek, a short distance south of the Weymarn No. 2 well. This may represent a southern extension of the grit. From Willow Creek the grit extends northwards a known distance of about seventy miles to the Jumpingpound district, where it is exposed in Sec. 26, Tp. 24, Range 5, W 5th Mer. It is exposed between these extremities, from the eastern edge of the foothills west to the Palaeozoics of the Rocky Mountains and it forms the backbone of many of the northwesterly trending ridges which characterize

Plate II



Outline map of Alberta with the thesis area outlined by the red.

PLATE II


NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
UNITED STATES
60°
120°
118°
110°
Fitzgerald
Slave R.
LAKE ATHABASKA
Peace River
Fort Vermilion
McMurray
Peace River
56°
Guardian Well
Grande Prairie
LESSER SLAVE LAKE
River
Athabaska
Athabaska
Edmonton
Saskatchewan River
North
Jasper
JASPER PARK
52°
Red Deer
Red Deer River
BANFF PARK
Banff
Calgary
Bow River
Medicine Hat
Lethbridge
PARK
49°
OUTLINE MAP OF ALBERTA
SCALE IN MILES
0 50 100 150 200

that region.

It has been reported from three wells drilled east of the foothills belt; the Anglo-Canadian Twin Dome No. 1 well, in Lsd. 10, Sec. 16, Tp. 21, Range 28, W 4th Mer., the Arca well in Lsd. 16, Sec. 13, Tp. 20, Range 29, W 4th Mer., and the Ranchmen's No. 1 well, in Lsd. 16 Sec. 24, Tp. 18, Range 1, W 5th Mer., but it has not been mentioned in the records of any of the wells drilled on the Alberta Plains.

Hume (1938, p. 3) reports the grit in the Wildcat Hills area, northwest of Cochrane. Evans (1929, p. 33) describes a conglomerate containing pebbles of chert and quartzite up to six inches in diameter, found on Ram river, occupying a stratigraphic position approximately the same as that of the grit. However, in view of the fact that the grit has almost lost its identity as a grit at Jumpingpound, the writer considers it unlikely that this conglomerate on the Ram river is the northern extension of the member.

Previous Studies

Dr. G.S. Hume informed the writer that he first observed the grit in 1926, on Sheep River near Macabee Creek, on the Turner Valley Sheet, and the name was first used by him in his report on the Highwood Jumpingpound Anticline etc. (1929). He described it as being composed of fine quartz grains and containing a few pebbles, and considered it to be a grit. Since that time the term

has come into common use, and the zone has been much used as marking the approximate contact between the Blairmore formation and the Alberta Shale formation.

Goodman (1935 p. 228-230) made a study of the Cretaceous rocks of Turner Valley, which included the examination of at least one thin section of this grit.

Present Study

The information on which this thesis is based has been gathered from three sources; the field, the laboratory, and the literature.

The writer spent several days in the field in September and October 1941, studying the grit at various localities in the foothills. In this work he was given valuable assistance by Fred A. McKinnon, B. Sc., whose advice was most helpful.

Field studies were extended from the vicinity of Meinsinger Lake, in Sec. 20, Tp. 15, Range 2, W 5th Mer., northward to Elbow river at Bragg creek, in Sec. 12, Tp. 23, Range 5, W 5th Mer., a distance of about sixty miles. So far as possible the most easterly outcrops of the zone were chosen for study, but in one or two cases it was found necessary to study outcrops a little further west.

Collections were obtained from eight different localities, four south of Highwood river, three between the Highwood and

Sheep rivers, and one from Elbow river. The stratigraphical section was measured in each case, and samples were taken and numbered from the top of the outcrop to the bottom. The various localities have been numbered from south to north as A1, A2, etc. (See Map 1), and the specimens therefrom have been designated as A1-1, A1-2 etc. Collections made by R.L. Rutherford at some of these locations in 1937 have also been studied.

A collection was made by the writer from Sullivan creek, on the Dyson creek sheet, during the summer of 1941, and this collection has been incorporated with the collections made in the main area assigned for study. Three specimens of what may be the equivalent to the grit on Beaver creek, in Tp. 6, Range 2, W 5th Mer., near Beaver Mines, Alberta, were kindly given to the writer by C.O. Hage, of the Geological Survey of Canada. In 1931 J.A. Allan and R.L. Rutherford collected specimens from a bed which is very similar to the grit, on Mill Creek, near Beaver Mines. These specimens have also been placed at the writer's disposal. D.B. Layer of the Oil and Natural Gas Conservation Board of Alberta provided chips from drill cuttings taken in Turner Valley.

In the field the beds immediately above and below the grit were observed wherever possible, and its exact stratigraphic position was carefully noted. The beds underlying the grit were only exposed at four localities, namely; A5, A7, A8, and on Sullivan creek. In all other cases the nature of the beds under-

lying the grit had to be inferred from bits of rock brought to the surface by burrowing animals.

Laboratory studies were mainly petrographic. Twenty-two thin sections, prepared from samples collected in the field, were examined under the microscope. In addition to the thin sections from the main area assigned for study, one prepared from drill cuttings taken in Turner Valley, and two prepared from material occupying about the same stratigraphic position in the Alberta Plains and the Beaver Mines Areas, have been examined. Immersion mounts of several specimens from the southern part of the thesis area were prepared and studied microscopically.

Using the knowledge gained in field and laboratory studies, combined with information gained from pertinent geological literature, the writer has attempted to answer the questions of the source and production of the sediments, the transportation, and the probable conditions under which they were deposited.

The theoretical portion of this thesis is largely based upon principles set forth by W.H. Twenhofel in his book, "Principles of Sedimentation".

Acknowledgements

The writer wishes to express his indebtedness to the members of the Department of Geology, who have made this work possible. Dr. R.L. Rutherford, under whose direction the work was done, has given generously of his time and advice, and Dr. J.A. Allan

and Dr. P.S. Warren have kindly advised the writer on certain phases of the work. The writer is also grateful for the use of specimens of grit which belong to the Department of Geology.

Many others have assisted the writer. Mr. C.O. Hage, of the Geological Survey of Canada, provided the writer with specimens from the Beaver Mines area, Alberta. D.B. Layer, of the Alberta Oil and Gas Conservation Board, gave the writer specimens from Turner Valley, and Dr. G.S. Hume, of the Geological Survey of Canada, provided information regarding the discovery and naming of the grit-bed. Mr. C.R. Stelck assisted the writer in consideration of certain correlations.

Summary and Conclusions

The grit or grit-bed has been studied in the field and in the laboratory. Lithologically, it has been found to consist of two well defined zones. The upper zone is conglomeratic in nature, and thickens to the south in the area studied. The lower zone is composed of hard quartz sandstones. The grit varies in thickness from a minimum of three feet to a maximum of seventeen feet in the area under consideration.

Petrographically the grit has been found to consist mainly of particles of quartz, well rounded, which have been subject to regrowth, and angular particles of rock, mainly chert, argillite, and quartzite. In the upper or coarse phase, the rock particles are the dominant constituents, and in the fine grained lower

phase, quartz grains are the dominant constituent. The cement is mainly quartz, which occurs as regrowth around old grains, and as a cryptocrystalline interstitial filling. Occuring less abundantly are the minerals zircon, tourmaline, mica, feldspars, and others.

It is concluded, mainly from petrographic study of the grit, that it is simply a zone of conglomerate and fine grained quartz sandstone. The coarse upper or conglomeratic phase could be properly called a pebble-grit, but the lower phase has none of the characteristics of a true grit.

The writer considers that the sediments of the grit were probably derived, largely by the processes of disintegration, from the central and western Rocky Mountains. Transportation was short, and may have been partly by wave action in the Alberta sea, and partly by streams flowing into the sea. The sediments appear most likely to have been deposited in the neritic zone, during a temporary halt in the rise of the level of the Alberta sea.

LITHOLOGY AND PETROGRAPHY

General Statement

The term "Grit", or "Grit-bed" is applied in Alberta to a thin zone of sandstone and conglomerate, which occurs within the lower 65 feet of the lower member of the Alberta Shale in the foothills west and south of Turner Valley.

The following extract from the report of the Committee on Sedimentation for 1935-36, of the National Research Council of the United States, briefly outlines the origin and general usage of the term "Grit".

> "'Grit' was first used as a provincial name for coarse grained sandstone. Some of the coarse siliceous sandstones termed grit were worked for millstones, and were called millstone grits. Later sharpness or angularity of grain became the distinguishing feature by which grits were separated from ordinary sandstone. Most of the millstone grits and grindstone grits were coarse grained sandstones, but grain size was not considered important so long as the grains of quartz were sharp. By others angularity of grain was not stressed so emphatically, and mention was made of small pebbles or gravel present in grits, but even by them particles are mentioned as gritty or rough." This report states that "In England the term is widely used for sandstones of angular grain, and by many for a coarse angular sandstone."

This committee recommended that the use of the term "grit" be restricted to coarse grained sandstones composed of angular particles, with the use of suitable adjectives to describe variations in the size of grain.

H.B. Milner (1929, pp. 276, 277), has the following to say of grits: "Every gradation from grits, in which the particles are equidimensional, through pebble grits, to conglomerates is met

with." He describes grits as having stratification normally developed on a large scale, and being characterized by the presence of stable accessory minerals. The predominant grains are angular, although usually some degree of rounding is exhibited.

Lithology of the Grit

General Description: The grit has been variously described. Hume (1933 p. 53) describes it in the Turner Valley area as "a fine conglomeratic zone with coarse, quartz sand beds from one to forty feet thick," --- closely associated with the base of the Alberta shale. West of Turner Valley the grit contains rounded waterworn pebbles which are supposed by Hume to have come from the Crowsnest volcanics. Excepting the supposedly volcanic pebbles, this description coincides with Hume's descriptions of the grit in the Pekisko Hills area, and the area between the north fork of Sheep river and Elbow river. Goodman (1935 p. 230), after petrogrophic study of the grit zone in Turner Valley, described it as a normal feldspathic grit.

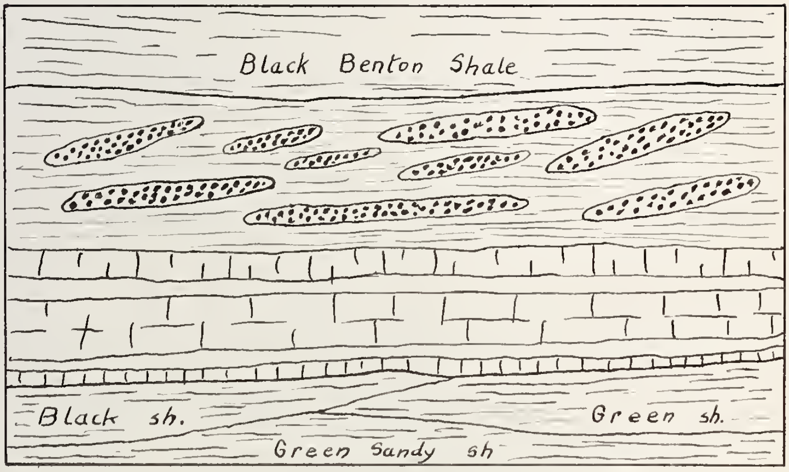
The most detailed lithologic description of the grit is that of P.D. Moore, which accompanies specimens of the grit sent to the Department of Geology in 1929.

> "The grit-bed is variable in thickness on outcrops from a minimum of about three feet to a maximum of ten to fifteen feet. These limiting thicknesses must be given because of the makeup of the bed or zone. Wherever seen, (and also from cores in the field) it consists of a series of grit lenses in the upper zone for the most part, which may be of all

sizes, from a fraction of an inch and about the shape of a pancake thinned on the edges. These lenses may be a few inches in diameter or a few feet, and are set in a matrix so to speak of typical black Benton shale, which is usually thinner than the lenses. On Sheep creek and the Highwood river, the bottom one to three feet consists of fairly even beds from a few inches up to one foot thick and almost invariably is finer grained. The upper or pancake beds or lenses are usually coarser, as (Figure 1).

It is this thin zone of beds that contains the first invariable show of oil or gas in Turner Valley, and not as Hume thought the green to buffish coloured shale which he calls tuff, which lies just beneath the grit-bed zone which he saw on outcrops on Sheep river west of Turner Valley."

Figure 1. (After P.D. Moore)



Sketch of the Grit Bed

In every locality at which the writer observed the grit, two distinct phases could be identified. The thickness of the whole zone varies from a maximum of about seventeen feet in the Pekisko Hills area to a minimum of three feet four inches on Highwood river.

The upper zone is always the coarser of the two, and is usually conglomeratic. In the Pekisko Hills area the upper zone is composed of a conglomerate, thinning from south to north, which contains well rounded chert and quartzite pebbles in a dominantly quartz matrix, and attains a maximum thickness of two feet at Meinsinger lake. This conglomerate is not present on Highwood river, where the upper zone is composed of three thin conglomerate beds interlaminated with thin gray sandstone beds and a small amount of black sandy shale. In the Elbow river area at Bragg creek, the upper zone is again conglomeratic. The contact of the upper zone with the overlying Alberta Shale is sharp wherever observed.

The lower zone, which is usually thicker than the upper zone, is composed of thinly bedded, hard, fine grained, gray quartz sandstones, with occasional lenses of conglomerate. At Meinsinger lake it is fifteen feet four inches thick, and it thins to the northward, being only about six inches thick on Highwood river. On Elbow river at Bragg Creek it is about eight feet thick. The contact of the lower zone with the beds beneath is sharp wherever observed, but is not often exposed.

The buff coloured shale or tuff mentioned by Moore is not always present. Where the writer examined the grit on Highwood river it lies directly upon typical black, sandy, Lower Alberta Shale. The same is true of the exposures studied on Sullivan

creek and Elbow river.

On Sullivan creek in Sec. 26, Tp. 18, Range 5, W 5th Mer., there is an excellent exposure of grit exhibiting the typical upper conglomerate phase and hard fine grained gray sandstone lower phase. The rock at this exposure is petrographically somewhat different from the grit in the main belt studied, but it is considered to be the grit on the basis of the stratigraphic position it occupies.

Descriptions of Sections Studied: The grit exposures studied in the field are here discussed in the order from south to north. In each case a list of the specimens taken, is given. Columnar sections of the exposures are shown in figure 2. The numbers assigned to the exposures and sections correspond with the localities indicated in Map 1.

AREA 1 - S.W. quarter of Sec. 20, Tp. 15, Range 2, W 5th Mer.

List of Specimens

A1 - 8a	Top of the zone. Conglomerate 24 inches thick.
A1 - 8	1 ft. 3 inches below the top
A1 - 7	2 " 4 " " " "
A1 - 6	7 " 4 " " " "
A1 - 5	11 " 9 " " " "
A1 - 4	13 " 9 " " " "
A1 - 3	15 " 4 " " " "
A1 - 2	16 " 6 " " " "
A1 - 1	17 " 6 " " " "

Total thickness of grit zone =

17 feet

In this area, outcrops of grit dipping west at 30° occur on the hills to the southeast and northeast of Meinsinger lake. The outcrop given special attention occurs on the crest of the small hill rising immediately northeast of the lake. Small scale slicing of the grit is apparent here, but the section measured shows no appreciable duplication.

The beds here exposed are largely quartzitic sandstones. The upper part is rather massive in character, with a conglomeratic phase about two feet thick at the top. The lower half of the section is less massive, and near the base there are two bands of thinly bedded gray sandstone, which are very hard and which exhibit a lamellar habit. These two bands are separated by a thin blocky sandstone. The whole zone weathers brownish in color. There is room for at least twenty-five feet of beds between the grit and the uppermost exposed bed of the Blairmore formation.

AREA 2 - N.E. quarter of Sec. 18, Tp. 16, Range 2, W 5th Mer. Five miles north of Area 1. Northeast of the A.P. Con. Sheppard Creek bore hole, on Sheppard Creek.

List of Specimens

A2 - 1	Top of the zone.
A2 - 2	1 ft. 4 inches below the top. Base of the conglomerate.
A2 - 3	3 ft. 4 inches below the top
A2 - 4	4 " 2 " " " "
A2 - 5	6 " 2 " " " "
A2 - 6	8 " 2 " " " "
A2 - 7	9 " 4 " " " " (Same bed as A2 - 6)
A2 - 8	12 " 8 inches below the top
A2 - 9	15 " 2 " " " "

A2 - 10	16 ft. 2 inches below the top
A2 - 11	17 " 4 " " " "

Total thickness of the grit zone =

17 feet 4 inches

The top bed of the zone here is a conglomerate one foot four inches thick, with a sandy matrix, and containing pebbles of gray and black chert up to four millimetres in diameter. This conglomerate appears to become somewhat finer grained near its base. It is directly underlain by more thinly bedded sandstone, which is very hard and quartzitic. The lower twelve feet of the zone is composed of hard quartzitic beds, gray to dark gray on fresh surfaces and weathering brown. These beds average from five to nine inches thick. There is no shaly sandstone such as was found near the base of the section at A1. There is room for fifteen to eighteen feet of beds between the base of the grit and the uppermost exposed Blairmore beds.

AREA 3 - N.E. quarter of Sec. 36, Tp. 16, Range 3, W 5th Mer. Three miles north of Area 2.

List of Specimens

A3 - 1	Top of the zone. Conglomerate 1 ft. 8 inches thick
A3 - 2	3 " below the top
A3 - 3	4 " " " " conglomerate 1 foot thick
A3 - 4	7 " 1 inch below the top
A3 - 5	9 " 2 " " " " to 9 ft 6 in. below the top
A3 - 6	12 " 8 " " " "
A3 - 7	15 " 6 " " " "

Total thickness of the grit zone = 15 ft. 6 inches

The conglomerate, which is the top member of the zone, is one foot eight inches thick. It contains gray and black chert pebbles, and is somewhat finer grained than at the two localities further south. Beneath this is a very hard, fine grained, quartzitic gray sandstone, which in turn is underlain by a fairly soft gray sandstone. Four feet from the top there is a one foot conglomerate bed carrying black and gray chert pebbles in a rather coarse matrix, which shows some porosity.

Nine feet from the top there is another conglomerate, six inches thick. It contains gray and black chert pebbles, fairly well rounded, of rice size.

With the exception of these two conglomerates the whole lower part of the zone is composed of hard quartzitic gray sandstones, which weather gray and light brown.

There is probably about fifteen feet of shale beds underlying the zone at this point.

AREA 4 - N.W. quarter of Sec. 6, Tp. 18, Range 2, W 5th Mer., seven miles north of Area 3, near Bull Creek. There are several bands of grit outcropping here but only one is sufficiently well exposed to be accurately measured.

List of Specimens

A4 - 1	Top.	1 foot thick				
A4 - 2	2 ft.	6	inches	below	the	top
A4 - 3	3 "	6	"	"	"	"
A4 - 4	4 "	6	"	"	"	"
A4 - 5	5 "			"	"	"
A4 - 6	5 "	6	"	"	"	"
A4 - 7	7 "			"	"	"

Total thickness of the grit zone =

7 feet.

The beds comprising the grit zone in this locality are all very hard, gray in colour, weathering brown. The conglomerate is much finer grained here than to the south, and has more of the general appearance of a coarse sandstone. The beds are rather brittle throughout the entire zone, and are all medium to coarse grained. The upper three feet of beds show some porosity.

Whether or not there is dark shale underlying the zone in this locality is not definitely known, since no evidence of its presence could be found.

AREA 5 - S.W. quarter of Sec. 34, Tp. 18, Range 3, W 5th Mer., five miles northwest of locality 4, on Highwood River. The section measured is exposed at the water's edge about one quarter of a mile above the confluence of Ings Creek with the Highwood River.

List of Specimens

A5 - 1	Top
A5 - 2	6 inches below the top
A5 - 3	10 " " " "
A5 - 4	22 " " " "
A5 - 5	26 " " " "
A5 - 6	40 " " " "

Total thickness of the grit zone =

3 feet 4 inches.

The grit zone is composed of hard, gray, thinly bedded quartzitic sandstone and thin conglomerate beds. Three distinct conglomerates are present, each containing mainly black chert pebbles. The highest is the top bed of the zone, the second is one foot ten inches below the top, and the third is two feet two inches below the top. None of these conglomerates exceed four inches in thickness. The beds interlaminated with the conglomerates are very hard, dark gray sandstone, and they contain a few pebbles of chert. None of these beds exceeds two inches in thickness.

In the zone is underlain by seventeen feet of black thinly laminated shale, below which lie typical Upper Blairmore sandstones.

AREA 6 - N.E. quarter of Sec. 4, Tp. 19, Range 3, W 5th Mer., two miles north of Area 5.

List of Specimens

A6 - 1	Top
A6 - 2	14 inches below the top
A6 - 3	24 " " " "
A6 - 4	48 " " " "

Total thickness of the grit zone =

4 feet

This is not a good exposure of the grit, but no other outcrops are found until Sheep river, three and one half miles northwest, in approached.

There is no distinct conglomerate here, although the beds are quite coarse. The zone is composed of very hard gray sandstones, coarse grained, weathering light brown. Fourteen inches below the top there is a thin bed made up of very coarse grains of black and gray chert. The lowest member of the zone is of a character very similar to this.

There is no shale exposed below this zone.

AREA 7 - S.E. quarter of Sec. 20, Tp. 19, Range 3, W 5th Mer., three miles northwest of Area 6.

List of Specimens

A7 - 1	Top
A7 - 2	6 inches below the top
A7 - 3	1 ft. 2 inches below the top
A7 - 4	1 " 10 " " " "
A7 - 5	2 " 4 " " " "
A7 - 6	4 " " " "

Total thickness of the grit zone =

4 feet

This is a fairly good exposure, in which the rocks bear a marked similarity to those exposed at Area 6. There is no conglomerate, the section being composed of hard, coarse gray sand, which weathers light brown. The coarsest phase is at the bottom. The whole lower part of the section increases in coarseness with increasing age.

Below the grit there is an exposure of dark shale, a rather poor outcrop but it serves to prove the presence of the shale. The thickness of the shale however is not known.

AREA 8 - N.W. quarter of Sec. 12, Tp. 23, Range 5, W 5th Mer., on the north bank of Elbow River one third of a mile above the bridge at Bragg Creek post office.

List of Specimens

A8 - 1	Top
A8 - 2	2 ft. 6 inches below the top
A8 - 3	4 " below the top
A8 - 4	6 " " " "
A8 - 5	7 " " " "
A8 - 6	9 " " " "
A8 - 7	11 " " " "
A8 - 8	12 " " " "
A8 - 9	14 " " " "

Total thickness of the grit zone =

14 feet.

The section is very well exposed here, as are the beds with which it is associated.

The upper six feet of the zone is dark gray porous rock, which is composed largely of quartz and chert grains. Underlying this there is five feet of hard, tight, quartzitic sandstone with

a thin bed of softer sand in its upper part. This is underlain by three feet of alternating hard, tight, quartzitic bands and softer light gray sands. None of these lower beds exceeds two inches in thickness. The rocks weather buff to brown.

The zone is overlain by the black fissile Lower Alberta Shales, and is underlain by sixteen and one half feet of dark, gray to black shale, considered to be Lower Alberta in age.

ADDITIONAL AREA - Sec. 26, Tp. 18, Range 5, W 5th Mer., on Sullivan Creek about fourteen miles upstream from the ¥ Ranch on Sullivan Creek.

During the summer of 1941 the writer was employed by the Geological Survey of Canada, under C.O. Hage, working on the Dyson creek sheet, which adjoins the Turner Valley sheet on the west, and had there an opportunity for studying the grit. A collection was made from the best outcrop in the area, and that collection is now incorporated into the suite collected further east in the foothills.

List of Specimens

S1 - 1	Top
S1 - 2	3 inches below the top
S1 - 3	6 " " " "
S1 - 4	8 " " " "
S1 - 5	14 " " " "

Total thickness of the grit zone =

1 foot 2 inches.

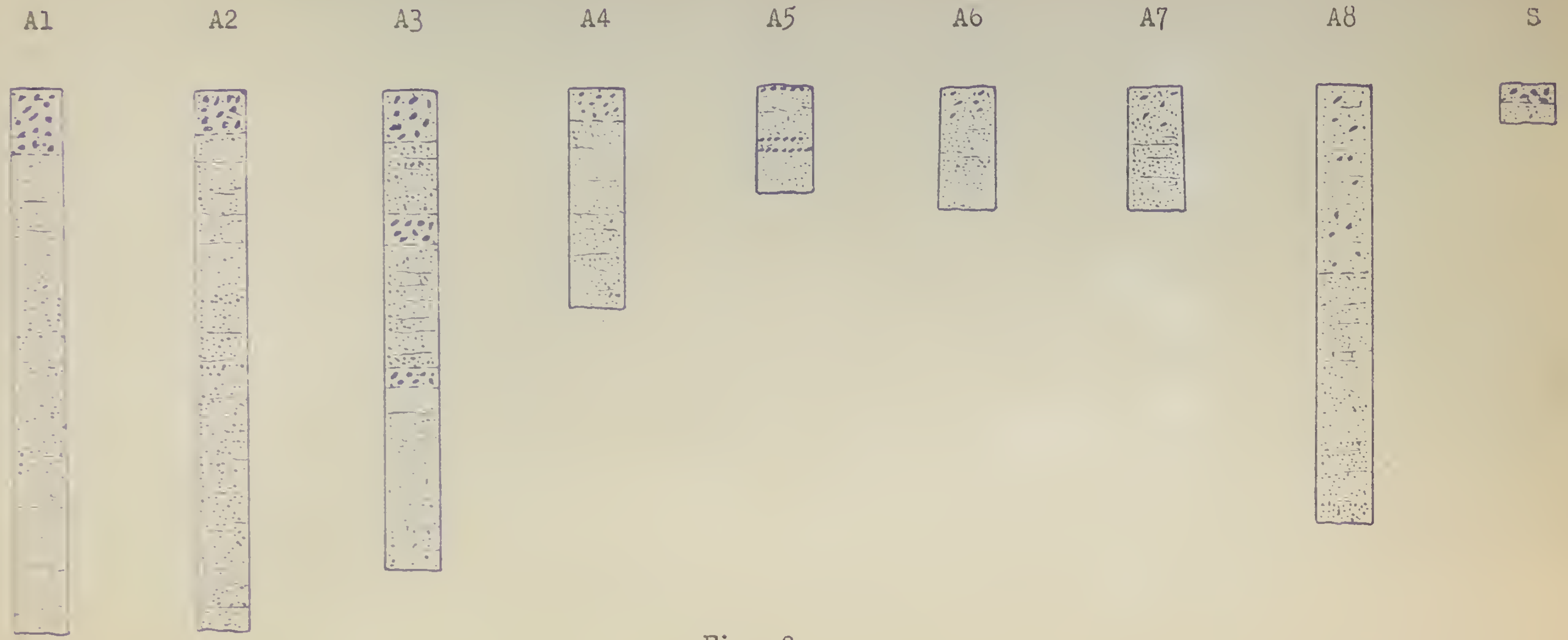


Fig. 2

Columnar Sections of the grit bed. Sandstone indicated by fine stippling, conglomerate by coarse and fine stippling. Scale 1 inch = 6 feet.

The zone on Sullivan Creek is made up of two distinct phases. The upper phase is a dark coloured, deeply weathered conglomerate, six inches thick. It contains well rounded dark gray and black chert pebbles in a dark calcareous matrix. The lower phase is a very hard medium grained gray sandstone, eight inches thick. This sandstone weathers buff coloured.

An interesting feature not noted elsewhere with the grit is its association in this locality with a two inch sandy shale band which exhibits cone-in-cone structure. This band is directly overlain by the grit zone.

The grit zone is underlain by sixty-five feet of somewhat sandy black fissile shale, typical of the Lower Alberta Shale.

Correlation

Outside of the area studied by the writer, the grit has not been definitely identified in the foothills.

J.A. Allan and R.L. Rutherford collected specimens of a coarse chert conglomerate from beds near the base of the Alberta Shale on Mill creek in Lsd. 4, Sec. 7, Tp. 6, Range 1, W 5th Mer., in the Beaver Mines area. This material is somewhat different petrographically from the grit, but on the basis of its stratigraphic position, the writer believes it may represent a southern extension of the grit. However since no exposures of the Alberta Shale-Blairmore contact have been examined between this area and Sec. 17, Tp. 13, Range 2, W 5th Mer., where the southernmost known exposure

of the grit occurs, this suggestion cannot be proven at the present time. Hume correlates a tuff bed, which outcrops on Highwood river, with the Crowsnest Volcanics. The grit overlies this tuff bed on Highwood river, and if Hume's correlation is correct, it lends strength to the writer's tentative correlation of the grit with the cert conglomerate, which overlies the Crowsnest Volcanics, on Mill creek.

Evans (1930, p. 33) describes a conglomerate containing pebbles of chert and quartzite up to six inches in diameter, which occurs at the top of the Blairmore on Ram River. A similar bed occurs on the south fork of Burnt Timber creek, and the Alberta Shale-Blairmore contact is said to be marked in some places by a bed of bentonite from six inches to one foot thick. (Hume, 1933, p. 53). The grit may correlate with the conglomerate beds on Ram river and Burnt Timber creek, but probably not with the bentonite bed mentioned by Hume, since on Sheep river (south fork) the grit is overlain by a one foot bed of bentonite.

In the Battle river area of the Alberta Plains, a fine chert conglomerate is reported from the base of the Alberta Shale in certain wells. This conglomerate may represent the grit in that area, since it occupies about the same stratigraphic position as the grit occupies in the foothills. A grit-like sandstone is found near the base of the Blackleaf member of the Alberta formation in the Southern Plains. This zone however is stratigraphically lower than the grit in the foothills.

Goodman (1935 p. 228) attributes to Hume a description of the grit as a rewashed volcanic ash, and correlation of the grit with the Crowsnest volcanics. In this respect Goodman has evidently misunderstood Hume's remarks. In his Turner Valley report of 1926 Hume describes a one foot bed of extremely porous volcanic tuff, containing a few pebbles, lying just below the base of the Alberta Shale. It is this tuff which he refers to as a reworked volcanic ash, and correlates with the Crowsnest volcanics. According to P.D. Moore this tuff occurs just beneath the grit-bed.

Petrography of the Grit

The grit exhibits essentially constant petrographical characteristics throughout the main area studied. The upper or conglomeratic phase is mainly composed of angular particles of rock, (chert, argillite, quartzite) and rounded quartz grains in lesser amounts. (Plate 3, No. 1). The lower phase which is finer grained, is composed mainly of quartz grains which usually exhibit regrowth of quartz. (Plate 3, No. 2). Rock particles may comprise up to thirty per cent of the fine grained rock of the lower phase. The minor constituents occur more abundantly in the fine grained lower phase than in the coarse grained upper phase. Quartz is the main cementing constituent.

The grit from Sullivan creek is decidedly different petrographically from the grit in the main belt studied, in that

authigenic carbonate minerals are the dominant cementing medium, particularly in the coarse phase, and regrowth of quartz is of relatively minor importance. The rock from Mill creek is petrographically quite similar to the grit from Sullivan creek.

The writer is doubtful of the possibility of reliable correlations of similar zones in other parts of the province with the grit, by petrographical methods. The fine grained lower phase of the grit particularly is not distinguishable from many of the sandstones of the Kootenay and Blairmore formations, and to a lesser extent of the Belly River formation. Coarse or conglomeratic phases of these formations have not been studied by the writer, so that it is not know whether the coarse phase of the grit has any petrographic features which would distinguish it from them.

In the following table the constituents of the grit are given as nearly as possible in order of abundance.

Composition

Detrital	Authigenic
Essential Rock particles, quartz. Minor Zircon, mica, chlorite, apatite, feldspar, tourmaline, magnetite.	Quartz, iron oxides, iron sulphide, calcite, siderite.

Essential Constituents: The most abundant of the essential constituents in the coarse phases are grains of chert, argillite,

and quartzite, with small amounts of other kinds of rock.

Chert occurs in grains of all sizes up to three millimetres, the larger of which are fairly well rounded. The grains are pale brownish-yellow to colourless, and under crossed nichols they show a cryptocrystalline mosaic extinction pattern. Small chalcedonic centres exhibiting radiating extinction in the form of a miniature black cross are common, and a few spherulites were observed. (Slide No. 17-13-2).

Argillite is also common. The grains are of variable size up to two millimetres and most of them are angular. The colour ranges from dark brown and almost opaque to pale brown. True argillite grains exhibit banding, particularly so in the darker grains. The texture is cryptocrystalline, commonly with a few coarser quartz centres.

There are many grains of rock which are intermediate between chert and argillite. They are light brown in colour, and cryptocrystalline, but they do not exhibit the chalcodonic centres characteristic of chert, nor the banding characteristic of argillite.

In most of the thin sections a few grains were observed which are of special interest for their optical properties. These grains are usually pale yellow in colour, and not well rounded. Under crossed nichols, these grains have the appearance of being isotropic, with a few very small centres of anisotropism. (Slide No. A1-8a). However in one thin section (No. A5-1) it was observed that grains identical with these are very finely cryptocrystal-

line, and it is the writer's opinion that these seemingly isotropic grains are merely particles of an extremely fine grained rock, probably of dominantly quartz or feldspar composition.

Quartzite occurs in small amounts in most of the thin sections. Chalcedony occurs as centres in chert, and in one thin section (No. A5-2) large, angular, clastic grains of chalcedony were observed.

Quartz is very abundant, and in the finer grained phases is the dominant clastic constituent. The average diameter of the quartz grains is less than 0.5 millimetres. The apparent angularity of the grains is in most cases due to regrowth of quartz around the clastic grains, usually in optical continuity with the old grain. This regrowth is clearly demonstrated by the crenulate edges and close interlocking of the grains, and the dust rims which are nearly always evident. In one slide (No. A1-8a, Plate 3, No. 3) several grains showed two dust rims, one within the other. This is interpreted by the writer to mean that these grains were derived from a previous sediment, in which well rounded quartz grains were subject to regrowth. The detrital quartz grains are usually of uniform size in any thin section.

Minor Constituents: In general, the minor constituents are more abundant in the fine grained phases. The grains are rarely greater than 0.1 millimetres in diameter.

Zircon is the most persistent of the minor minerals, occur-

ing in nearly all the thin sections examined. (Plate 3, No. 5). The grains are characterized by their high relief and birefringence. They are usually well rounded.

Flakes of mica, and chloritic material are present in small amounts in most of the thin sections. Biotite and muscovite are the common micas. Apatite is fairly common in the Highwood river grit, but not elsewhere. The mineral is clastic but in most cases it shows pitted surfaces and other signs of solution. (Turner Valley thin section).

Feldspar, most of which exhibits albitetwinning, was observed in a few sections. The composition in all cases was determined as about Ab 60-65-An 40-35. It is possible that feldspar is present in the untwinned form in most of the fine grained sections, but only a few grains were identified. Tourmaline occurs in only a few slides, as very small rounded grains. (No. A7-1). Magnetite may be present in one slide. (No. A6-3).

Authigenic Constituents: Quartz is the most abundant authigenic material and is the common cementing medium. It occurs in every thin section as regrowth around old quartz grains and as a cryptocrystalline interstitial filling. Iron oxides are present in all the sections, but never in large amounts. The brown oxide is the usual type, but in one section (No. A2-1) a small amount of red oxide was observed. The oxides occur as a thin coating around the grains and sometimes as a cavity filler.

In slides S-2 and S-4 calcite is very abundant as an interstitial filling, but it is not present in important amounts in any of the other slides. Iron sulphide, probably mostly marcasite, is present in a few slides. It is very abundant in No. S-2, (Plate 3, No. 4). In two slides, very small spherulitic rhombs of siderite were observed. (Nos. A8-R and S-2). With the exception of siderite, all the authigenic minerals serve as cementing materials.

Classification of the Grit

Since the two zones of the so-called grit are dissimilar, they cannot properly be classified as a unit.

Neither zone is a true grit according to correct usage of the term. The upper zone, being conglomeratic in nature, may properly be called either a pebble-grit, or a conglomerate. The lower zone is simply a quartz sandstone of variable grain size, with a dominantly quartz matrix in which the clastics are on the whole well rounded, the apparent angularity of the quartz grains being due to regrowth of quartz around old grains.

Thin Section Descriptions

Key to the Locations of Specimens Studied Petrographically

No. 17-13-2	(Rutherford)	Willow Creek District
No. A1-8a	Upper Phase	Meinsinger Lake
No. A1-5	Lower Phase	" "
No. A2-1	Upper Phase	Sheppard Creek
No. A2-5	Lower Phase	" "
No. A3-1	Upper Phase	South of E.P. ranch, Pekisko Creek
No. A3-5	Lower Phase	South of E.P. ranch, Pekisko Creek
No. A4-1	Upper Phase	Bull Creek
No. A4-3	Lower Phase	" "
T.V. 1	(Layer)	Turner Valley
No. A5-1	Upper Phase	Highwood River
No. A5-2	Upper Phase	" "
No. A5-5	Upper Phase	" "
No. A6-1	Upper Phase	Between Highwood and Sheep Rivers.
No. A6-3	Lower Phase	Between Highwood and Sheep Rivers
No. A7-1	Upper Phase	Between Highwood and Sheep Rivers
No. A7-4	Lower Phase	Between Highwood and Sheep Rivers
No. A8-1	Upper Phase	Elbow River at Bragg Creek
No. A8-6	Lower Phase	" " " " "
No. A8-R	(Rutherford)	" " " " "
No. 1565JP	(Rutherford)	Jumpingpound
No. S2	Upper Phase	Sullivan Creek
No. S4	Lower Phase	" "
M.C. 1	(Rutherford)	Mill Creek

No. 17-13-2.

Macroscopic Description

This rock is a well indurated aggregate of small pebbles and coarse grains of gray and black chert. The fracture is uneven and considerable breaking through the grains is observed. The colour is gray, and the weathered colour is gray.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Chert, argillite shale, quartz	Quartz, iron oxides, iron sulphide
Minor	
Zircon, tourmaline, biotite	

About 80% of the whole is composed of rock fragments. Chert is the most abundant, being present in clean, cryptocrystalline grains, generally well rounded, a few of which exhibit spherulitic texture. Argillite grains are also abundant. They usually show some banding, and are stained varying shades of brown. The argillite grains are more finely cryptocrystalline than are the cherts, and some are dark brown in colour and are opaque. Quartz grains compose about 10% of the rock. The grains have strong dust rims and crenulated edges, and are closely interlocked with neighboring grains, indicating that regrowth has taken place around the old grains.

The most abundant minor mineral is iron sulphide, probably marcasite. Associated with it is iron oxide. Small, clear, well rounded zircons are also fairly abundant. A few grains of biotite, and tourmaline, are also present.

The main authigenic constituent is quartz, occurring as regrowth around old grains, and as a cryptocrystalline interstitial filling. Iron oxides also serve as cementing material, though to a lesser extent than quartz.

Average Grain Size

Chert grains, 0.5 to 2.0 mm. diameter.
Quartz grains, 0.25 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A1-8a.

Macroscopic Description

A medium to fine grained conglomerate. The pebbles are of gray and black chert and quartz, the quartz pebbles being smaller than the chert. The rock fractures through the grains.

Microscopic Description

Composition

Detrital	Authigenic
Essential Chert, argillite, shale, quartz.	Quartz, iron oxides, siderite
Minor Chlorite, biotite, zircon	

Chert and argillite particles comprise about 75% of the rock. Of these chert is the most abundant. Some of the chert is spherulitic, and contains one or two chalcedonic geodes. The chert grains are clean and fairly well rounded. Argillite particles are abundant. The argillites are stained yellowish brown to dark brown and opaque. One of the argillite particles is cut by a small cryptocrystalline vein of quartz. Quartz grains make up about 20% of the rock. They have marked dust rims and are closely interlocked. They are of special interest in that some grains show two dust rims in subconcentric arrangement. (Plate 3, No. 3). There are also a few grains of very finely cryptocrystalline rock which is probably mainly made up of quartz, although under crossed nichols it appears isotropic, with very small anisotropic centers within. It is transparent, and pale yellow in colour under plane polarized light.

Chlorite or chloritic material is the most abundant of the minor constituents. The grains are thinner than 0.03 mm., and therefore identification was not positive. There a few very small particles of biotite, and one zircon was observed.

The authigenic content is mainly quartz, as regrowth around old grains, and as a cryptocrystalline interstitial filling. There is also a small amount of iron oxide. Abundant small rhombs of siderite, some of which have spherulitic texture, were observed.

Average Grain Size.

Rock grains, 1.4 mm. diameter.
Quartz grains, 0.8 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. Al-5.

Macroscopic Description

This is a fine grained gray sandstone, weathered deeply to a brownish gray colour. The fracture is fairly even in one direction, and uneven at right angles to it.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert argillite, shale, other rock	Quartz, iron oxides
Minor	
Chloritic material, tourmaline, biotite, apatite, feldspar.	

Quartz makes up about 75% of the rock. The grains are closely interlocked, and show crenulated edges. Dust rims are usually absent. Many of the grains contain minute inclusions. Chert grains are the most abundant rock particles, and they make up about 10% of the rock. They are clean and well rounded and generally small. Argillite makes up about 10% of the rock. The grains are banded, cryptocrystalline, and brownish in colour. A few grains of shale are present and also a few grains of the very fine rock material described in slide No. Al-8a.

The most abundant of the minor minerals is chlorite, which is well disseminated throughout the rock. Tourmaline is present in clear rounded grains, and flakes of biotite occur. Zircon is present, but not common. A few grains of apatite, some relatively undecomposed, and two pieces of orthoclase were observed.

The material is mainly quartz, occuring as regrowth around old grains, and as interstitial fillings. The cryptocrystalline interstitial quartz is very abundant in this section. Iron oxides are also present as cementing matter.

Average Grain Size

Quartz grains, 0.14 mm. diameter.
Chert and argillite grains, less than 0.5 mm. diameter.

No. A2-1.

Macroscopic Description

A fine grained conglomerate, with gray and black pebbles of chert embedded in a fine grained matrix of chert. It is gray in colour, and weathers brownish gray. The rock is brittle, and it fractures unevenly through the grains.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, shale Minor Biotite, feldspar, zircon, quartzite.	Quartz, iron oxides, iron sulphide

Clastic quartz makes up about 70% of the rock. The grains show dust rims, and are closely interlocked, indicating regrowth of quartz around old grains. Chert makes up about 15% of the rock. The grains are clean and well rounded, and generally larger than the quartz grains. Some chacedony is intergrown with the chert. Argillite comprises about 10% of the rock, the grains being brownish in colour and exhibiting some banding. A small amount of other very finely cryptocrystalline rock was observed. (See slide No. A1-8a).

The most common of the minor minerals is biotite, partially altered to chlorite. It is concentrated in a small area of the slide. Feldspar, showing the albite law, and several untwinned grains, was observed. A few well rounded grains of zircon and two grains of quartzite are present.

The main authigenic mineral is quartz, which is present as regrowth around well rounded old grains, and as a cryptocrystalline interstitial filling. The iron oxides, small amounts of which are distinctly red, also serve as cementing material. Iron sulphide is present, probably largely altered to brown and red oxide.

Average Grain Size

Matrix grains, 0.4 mm. diameter.
Pebbles, up to 4.0 mm. in diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A2-5.

Macroscopic Description

This is a well indurated light gray coloured quartz sandstone. It is very fine grained, and has an uneven fracture which tends to be conchoidal in contour. It weathers reddish brown.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert, argillite	Quartz, iron oxides
Minor	
Muscovite, feldspar, tourmaline, zircon.	

About 85% of the rock is composed of quartz. The grains are closely fitted together, and exhibit dust rims and crenulated edges, indicating regrowth after deposition. Rock particles, mainly chert, comprise about 10% of the whole. Regrowth of cryptocrystalline quartz has occurred around many chert grains, and some chalcedonic centers in the chert grains were noted. There are also a few grains of argillite.

Muscovite is the most abundant minor mineral. It occurs in very small, rounded flakes, well disseminated throughout the rock. Feldspar is present, one grain showing fine albite twinning, and having a remarkably fresh appearance. It was determined to be of Ab50-An50 composition. One rounded grain of tourmaline, and at least one zircon were observed.

The chief authigene is regrowth of quartz around old chert and quartz grains, with a smaller amount filling the interstices between grains. A smaller amount of iron oxide serves as a cement and as a cavity filler.

Average Grain Size

Quartz grains, 0.25 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A3-1.

Macroscopic Description

A coarse conglomeratic quartz sandstone, containing a few small chert pebbles. Gray in colour, fracture rough and uneven. Some iron staining is evident.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, argillite, chert, quartzite, other rock Minor Chlorite, muscovite, zircon, tourmaline, feldspar.	Quartz, iron oxides

Quartz grains constitute about 75% of the rock. The grains are closely interlocked, and exhibit strong dust rims, indicating that regrowth has taken place. The dust rims indicate that the grains were well rounded. Argillite grains, angular in outline, comprise about 15% of the rock, and chert grains, also angular, comprise about 5%. There are a few grains of quartzite, and of the finely cryptocrystalline rock described in slide A1-8a.

Chlorite, or chloritic material, is the most abundant of the minor minerals. It occurs in small patches, well disseminated throughout the rock. Muscovite is present in very small grains. Zircons are fairly abundant, and somewhat more angular than usual. Several very large grains were observed. Three well rounded grains of tourmaline occur in a group. Two pieces of feldspar, both exhibiting the albite law were observed, and their composition was determined as Ab55-An45.

The authigenic material is mainly quartz. Regrowth around old quartz grains is commonest, but there is some of the interstitial variety. A small amount of iron oxide also serves as cementing material.

Average Grain Size

Quartz grains, 0.45 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A3-5.

Macroscopic Description

A fine grained, well indurated conglomerate, with small pebbles of quartz, and gray and black chert. The matrix and some grains carry an iron oxide stain. The fracture is uneven and rough.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Chert, argillite, quartzite.	Iron oxides, quartz.
Minor	
Quartz	

Chert makes up about 60% of the rock. The grains are angular and up to 4 mm. in diameter. Small chalcedonic centers are very common. Argillite is also abundant, the grains being angular, and brown to nearly black in colour. Many grains exhibit excellent banding. Argillite makes up about 25% of the rock. Quartzite is also present as angular grains, making up about 10% of the rock. Quartz is present in a minor amount. The grains show dust rims, and some are cracked or shattered.

The main authigenic mineral is iron oxides, mostly the brown varieties. However small amounts of red oxides were observed. Quartz is present in small amounts, as regrowth around old quartz grains, and some of the chert grains. It also occurs in small amount as a cryptocrystalline interstitial filling.

Average Grain Size

Chert grains, 2 mm. diameter.
Argillite and quartzite grains, up to 2 mm. diameter.

No. A4-1.

Macroscopic Description

This is a medium to coarse grained gray sandstone, composed of grains of quartz and chert in a quartz matrix. The fracture is uneven.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert, argillite, quartzite	Quartz, iron oxides
Minor	
Muscovite, zircon, chlorite, tourmaline.	

Quartz is the most abundant constituent, comprising about 60% of the rock. The grains show very strong dust rims. These, and the crenulated edges and interlocking of the grains, indicate regrowth of the quartz. Angular chert grains make up about 25% of the rock. Many of the grains have minute chalcedonic centers. Argillite makes up about 5% of the rock. The grains are angular, and they exhibit banding to varying degrees. A few grains of quartzite are present, and a small number of grains intermediate between chert and argillite.

The minor minerals are present in very small amounts. Muscovite is the most abundant, occuring as very small flakes. Zircons are well rounded, and few in number. Chlorite was observed in one place in a small amount, and three nearly prismatic grains of tourmaline are present.

The chief authigene is quartz occuring as regrowth around old grains, and as an interstitial filling. Iron oxides are also abundant as cementing material.

Average Grain Size

Quartz grains, 0.80 mm. diameter.
Chert grains, less than 1.0 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A4-3.

Macroscopic Description

A well indurated fine grained gray sandstone. The rock is thinly bedded and has an uneven fracture. Strongly iron stained on the weathered surface.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, quartzite, other rock	Quartz, iron oxides
Minor Feldspar, apatite, muscovite, chlorite, tourmaline.	

Quartz grains with well rounded dust rims make up about 65% of the rock. The grains are closely interlocked, and have crenulated edges. Chert comprises about 15% of the rock. The grains appear to be angular, but often the true shape is masked by regrowthof quartz. The chert exhibits small chalcedonic centers. Typical dark argillite grains, angular in outline, are common, comprising about 10% of the rock. There are a few grains of quartzite, and a few of chalcedony. There are also a few grains which appear to be partly isotropic, (See slide A1-8a), but they are actually anisotropic.

Feldspar is the most abundant minor mineral. It exhibits albite twinning, and was determined to be Ab60-An40 in composition. With the exception of one or two relatively fresh grains, the feldspar is badly decomposed. Apatite is less common, occuring as rounded grains, some of which show the effects of solution. Flakes of muscovite occur sparingly throughout the rock, and some chlorite was observed, and two or three grains of tourmaline.

Quartz, occuring as regrowth around old grains, and as an interstitial filling, is the main authigene. In many cases this regrowth has masked the original shapes of the grains. Brown iron oxides are also important as cementing matter.

Average Grain Size

Quartz grains, 0.4 mm. diameter.
Chert and argillite grains, less than 0.6 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

T.V. 1. (Layer)

Binocular Description

The rock is a very fine conglomerate, composed of subangular chert and quartz grains enclosed in a fine yellowish brown matrix. It fractures unevenly through the grains. It is dark gray in gross colour.

Microscopic Description

Composition

Detrital	Authigenic
Essential Chert, quartz. Minor Apatite, rock grains.	Quartz, iron oxide, pyrite.

Chert comprises about 50% of the rock. It is clean and fairly well rounded. Fairly large clear quartz grains are present, containing many minute inclusions. The grains have crenulated edges, and interlock closely, indicating regrowth around old grains. Quartz makes up about 20% of the rock.

The most abundant of the minor minerals is apatite, which is clastic, as indicated by its granular form, but it shows signs of solution. One or two grains of the very fine grained rock described in section No. Al-8a were observed.

The authigenic material is mainly interstitial quartz and quartz regrowth around old grains, supplemented by small amounts of iron oxides. Iron sulphide, dendritic in habit, is also abundant.

Average Grain Size

Chert grains, 0.65 mm. to 1.25 mm. diameter.
Quartz grains, 0.25 mm. diameter.
Minor constituents, less than 0.5 mm. diameter.

No. A5-1.

Macroscopic Description

This is a well indurated, black, conglomeratic sandstone, composed mainly of chert and quartz grains, and a few small chert pebbles. The fracture is uneven. Some iron staining is evident.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, other rock Minor Apatite, chlorite, zircon.	Quartz, iron sulphide, iron oxides.

About 40% of the rock is composed of quartz. Dust rims are not common, but the crenulated edges of some quartz grains indicate that regrowth has occurred. Although the chert and argillite are hard to distinguish here, due to the heavy coating or iron sulphide on many of the grains, chert is thought to be the more abundant. Some chert grains have been cracked and recemented with cryptocrystalline quartz while still attached to the parent rock. Chert and argillite comprise about 45% of the rock. A few grains of rock are present which appear isotropic under crossed nichols. One of these grains however is distinctly cryptocrystalline in part, and the writer believes this material to be merely an extremely fine grained rock, probably largely quartz or feldspar. (See slide No. A1-8a).

Minor minerals are present in very small amounts. Apatite, occuring in very small grains which show signs of solution, is the most abundant. Two or three grains of chlorite were observed. The zircons are very small and were only seen in two places.

Interstitial quartz is the main authigenic material here, but there is some regrowth of quartz around old quartz grains. Iron sulphides are exceptionally abundant, coating many of the grains. Brown iron oxides are also present.

Average Grain Size

Quartz grains, 0.4 mm. diameter.
Chert and argillite grains, less than 1 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A5-2.

Macroscopic Description

The rock is dark gray in colour and very hard, being composed largely of chert grains in a quartz matrix. A few small pebbles of chert are present. The fracture is uneven and rough.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Chert, quartz, argillite, quartzite	Quartz, iron sulphides, carbonates (?)
Minor	
Apatite, biotote, muscovite	

About 65% of the rock is composed of chert. The grains are angular, and contain many chalcedonic centers. Quartz grains, most of which have strong dust rims and crenulated edges, make up about 20% of the rock. The quartz grains are noticably uniform in size. Argillite grains, and a few quartzite grains, make up about 10% of the rock. Small veinlets cryptocrystalline quartz, cutting detrital and authigenic constituents alike, indicate that the rock has been fractured and recemented after lithification.

Apatite is the most abundant of the minor minerals. The grains are disseminated throughout the rock, and pitted surfaces on the grains show that they have been subject to some solution. A few very small cleavage flakes of biotite, and two grains of muscovite were observed.

The most abundant authigenic mineral is quartz, filling the interstices between the grains, and as regrowth around detrital quartz. It is the main cementing constituent. Iron sulphide, probably marcasite, is very abundant, particularly as a coating around grains of chert and argillite. Probably there are also small amounts of carbonates present.

Average Grain Size

Chert grains, 1.3 mm. diameter.
Quartz grains, 0.5 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A5-5.

Macroscopic Description

Quartz grains and chert grains up to three mm. in diameter are cemented together in a quartz matrix. Very small nodules of marcassite are present. The colour is dark gray, and the fracture uneven.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, quartzite, chalcedony Minor Apatite, zircon, chlorite	Quartz, iron sulphides, carbonates, iron oxides.

About 40% of the rock is made up of quartz. The quartz grains exhibit strong dust rims, and many of them are shattered or cracked. Close interlocking and crenulated edges are characteristic of the quartz grains. Chert grains are larger than the quartz and are very angular. Spherulites of chalcedony, exhibiting miniature black cross extinction figures under crossed nichols, are common to chert. Chert comprises about 35% of the rock. Grains of argillite, quartzite, and chalcedony are all angular, and make up about 15% of the rock, argillite being the most abundant.

Apatite is the most abundant minor mineral, occuring throughout the slide in rounded grains, the larger of which show the effects of solution. Zircon is less common. The zircon grains are well rounded. Two thin flakes of chlorite were observed.

The commonest authigenic mineral is quartz, occuring as regrowth around detrital quartz, and as an interstitial filling of cryptocrystalline texture. It is the chief cementing matter. Iron sulphide, probably marcasite, is very abundant in small nodules, and as a grain coating. Carbonate minerals are a fairly common cement, and a small amount of iron oxides was also observed.

Average Grain Size

Quartz grains, 0.6 mm. diameter.
Chert grains, 1.1 mm. diameter.
Minor constituents, less than 0.2 mm. diameter.

No. A6-1

Macroscopic Description

This is a fine grained siliceous sandstone, containing a few coarse grains of chert. Some iron staining is evident. The fracture is uneven and rough.

Microscopis Description

Composition

Detrital
- Essential
  - Quartz, chert, argillite, quartzite
- Minor
  - Feldspar, chlorite, muscovite, zircon

Authigenic
- Quartz, iron oxides, carbonate(s)

Crenulate interlocking quartz grains comprise 60% of the rock. The quartz grains are fairly uniform in size, and well defined dust rims are common. About 25% of the rock is composed of chert. The chert grains are angular, and are characterized by small chalcedonic centers. Angular argillite particles make up about 10% of the rock. A few angular grains of quartzite were observed.

Feldspar is the most abundant minor mineral. Some of the feldspar grains exhibit albite twinning, and their composition was determined to be Ab65-An35. The feldspar grains are not fresh in appearance. Chlorite occurs in small patches. Muscovite is present in very small flakes, and a few well rounded zircons were observed.

The main authigenic mineral is quartz, occuring as a regrowth around detrital quartz, and as a cryptocrystalline interstitial filling. Iron oxides of the brown varieties also serve as cementint material. A very small amount of carbonate mineral was also observed.

Average Grain Size

Quartz grains, 0.3 mm. diameter.
Chert grains, 0.6 mm. diameter.
Minor constituents, less than .2 mm. diameter.

No. A6-3.

Macroscopic Description

A medium grained gray quartz sandstone, with a few chert grains. Occasional chert pebbles are present. The fracture is uneven.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert, argillite, quartzite, other rock.	Quartz, iron oxides
Minor	
Feldspar, zircon, magnetite (?)	

About 75% of the rock is made up of quartz. The quartz grains show dust rims, and crenulated edges, and are closely interlocked with neighboring grains. Chert, very finely cryptocrystalline, occurs in angular grains, making up about 15% of the rock. Angular argillite grains, and a few angular quartzite grains compose about 5% of the rock. A few grains of the very fine grained rock described in slide A1-8a were observed. Many of the detrital grains are cracked or shattered.

Feldspar, some of it fresh and exhibiting albite twinning, is the most abundant minor constituent. The composition was determined to be Ab65-An35. Some untwinned feldspar is also present. A few well rounded zircons were observed. Magnetite may be present in small amount, but it was not positively identified.

Quartz is the most abundant authigenic mineral. It occurs as regrowth around detrital quartz, and as an interstitial filling of cryptocrystalline texture. Brown iron oxides are also present as an interstitial filling.

Average Grain Size

Quartz grains, 0.5 mm. diameter.
Chert grains, less than 1.0 mm. diameter.

No. A7-1.

Macroscopic Description

This is a fine grained, hard quartz sandstone, with small amounts of carbonate in the matrix. The facture is uneven.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, chalcedony other rock.	Quartz, iron oxides, carbonate(s)
Minor Chlorite, tourmaline, zircon	

About 80% of the rock is composed of quartz. Quartz grains show dust rims, and some show two in sub-concentric arrangement. (See slide No. A1-8a). The quartz grains have crenulated edges and they are closely interlocked with neighboring grains. Chert grains are angular, and they exhibit many chalcedonic centers. Chert makes up about 10% of the rock. About 5% of the grains are argillite, exhibiting banding, and in a few cases, spherulitic texture. A few particles of extremely fine grained rock were observed. (See slide No. A1-8a).

Minor minerals are scarce. Chlorite is the most abundant, and was observed in two or three places. Two grains of tourmaline, which are evidently almost basal sections, were identified. One large angular zircon was noted.

Quartz is the main authigenic mineral. It occurs as regrowth around detrital quartz, and as a cryptocrystalline interstitial filling. Iron oxides, mainly the brown varieties, but with small amounts of red oxides, also are present in abundance. A very small amount of carbonate mineral was observed.

Average Grain Size

Quartz grains, 0.3 mm. diameter.
Chert and argillite grains, less than 0.6 mm. diameter.
Minor constituents, less than 0.2 mm. diameter.

No. A7-4.

Macroscopic Description

A fine grained quartz sandstone with a few grains of chert, and with a considerable amount of iron oxides in the matrix. The fracture is uneven.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, quartzite other rock	Quartz, iron oxides
Minor Zircon, apatite, tourmaline, muscovite, chlorite (?)	

Quartz comprises about 80% of the rock. The quartz grains have been subject to regrowth, and crenulated edges and dust rims are characteristic of the mineral. Chert and argillite particles make up about 15% of the rock, the grains being angular and of uniform size. Many of the argillite grains are very dark brown in colour, and opaque. A few particles of very fine grained rock are present. (See slide No. A1-8a).

Zircon as well rounded grains is the most abundant minor mineral. Several grains of apatite and a few grains of tourmaline w were observed. Two large flakes of muscovite are present. Chlorite, or possibly particles of schist are fairly abundant in some places.

The chief authigene is quartz, occuring as regrowth around detrital quartz, and as an interstitial filling.

Average Grain Size

Quartz grains, 0.3 mm. diameter.
Chert and argillite grains, less than 0.5 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A8-1.

Macroscopic Description

This is a gray siliceous rock, composed dominantly of quartz and chert grains, and exhibiting porosity. The fracture is uneven, and the rock crumbles readily due to the porosity.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert, argillite, chalcedony, other rock.	Quartz, iron oxides.
Minor	
Zircon, tourmaline	

Quartz comprises about 60% of the rock. The quartz grains have crenulated edges, and interlock with neighboring grains, but dust rims are generally absent. Angular chert grains make up about 30% of the rock. Spherulites and chalcedonic centers are common in the chert. Well banded angular argillite particles comprise about 5% of the rock, and a few angular particles of extremely finely cryptocrystalline rock were observed.

Only two minor minerals were observed. Zircon occurs in very small well rounded grains, and a few well rounded pieces of tourmaline are present.

Quartz is the most abundant authigenic mineral, occuring as regrowth around old quartz grains, and as a cryptocrystalline interstitial filling. Brown iron oxides occur as a cavity filler.

Average Grain Size

Quartz grains, 0.4 mm. diameter.
Chert grains, 0.7 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. A8-6.

Macroscopic Description

This rock is a very fine grained, well indurated quartz sandstone, with an uneven fracture. It apparently fractures through grains and matrix alike.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert, argillite, quartzite	Quartz, iron oxides, iron sulphide, some carbonate(s)
Minor	
Apatite, mica, chloritic material (?)	

Quartz makes up about 75% of the rock. Quartz grains have crenulated edges, and are closely interlocked with neighboring grains, and a few show dust rims. Angular grains of chert, some of which contain chalcedonic centers, comprise about 10% of the rock. Argillite grains, some of which exhibit strong banding, comprise about 10% of the rock.

Apatite is the most abundant of the minor minerals. The apatites are strongly pitted, suggesting that the mineral has been subjected to the action of solvents. Mica was observed, and possibly chloritic material, but this latter material may be particles of schist.

The chief authigene is quartz, occuring as regrowth around detrital quartz, and as an interstitial filling. Iron oxides, and iron sulphide, probably marcasite, are abundant. A small amount of carbonate mineral was observed.

Average Grain Size

Quartz grains, 0.2 mm. diameter,
Chert and argillite grains, less than 0.4 mm. diameter.
Minor constituents, less than 0.2 mm. diameter.

No. A8-R.

Macroscopic Description

A fine grained conglomerate, with pebbles of gray and black chert up to three millimeters in diameter, in a quartz matrix. The rock weathers brownish-gray.

Microscopic Description

Composition

Detrital	Authigenic
Essential	
Quartz, chert, argillite, quartzite	Quartz, iron oxides, siderite (?)
Minor	
Zircon, mica.	

Quartz comprises about 50% of the rock. The quartz grains exhibit strong dust rims and are closely interlocked with neighboring grains. Very clean angular chert grains with chalcedonic centers comprise about 35% of the rock. The chert grains average twice the size of the quartz grains. Angular argillite and quartzite particles make up about 10% of the rock.

The minor minerals are not abundant. Well rounded zircons are commonest. One zircon occurs within a chert particle. A few flakes of mica were also observed.

Quartz, as regrowth around detrital grains and as a cryptocrystalline interstitial filling, is the chief authigenic mineral. Brown iron oxides are also abundant as a coating on a few of the grains, and as a cavity filler. A very small amount of what is likely siderite occurs in minute rhombs.

Average Grain Size

Quartz grains, 0.4 mm. diameter.
Chert grains, 1.2 mm. diameter.
Minor constituents, less than 0.1 mm. diameter.

No. 1565 J.P.

Macroscopic Description

This is a fine grained, dark gray quartzitic sandstone, with some iron staining. The rock is brittle and fractures unevenly.

Microscopic Description

Composition

Detrital	Authigenic
Essential Quartz, chert, argillite, quartzite, chalcedony. Minor Feldspar, zircon, tourmaline	Quartz, iron oxides

About 80% of the rock is composed of quartz. Quartz grains commonly have dust rims and crenulated edges. Particles of chert, argillite, chalcedony, and quartzite comprise about 15% of the rock. Chert and argillite particles are present in about equal amounts, and are the most abundant of the rock particles.

Feldspar is the most abundant minor mineral, both fresh and altered particles being present. Some grains exhibit albite twinning and their composition was determined to be Ab60-An40. Zircon was observed but is not abundant. Three grains of tourmaline were noted. They exhibit strong pleochroism.

The chief authigene is quartz, occuring mainly as regrowth around detrital quartz grains, with a small amount of the cryptocrystalline interstitial variety. Brown iron oxides were observed, coating a few of the grains.

Average Grain Size

Quartz grains, 0.3 mm. diameter.
Rock grains, 0.4 mm. diameter.
Minor constituents, less than 0.2 mm. diameter.

No. S-2.

Macroscopic Description

The rock is a dark gray conglomerate, well indurated, with black chert pebbles up to five millimeters in diameter, in a dominantly carbonate matrix. A small amount of marcasite is present.

Microscopic Description

Composition

Detrital	Authigenic
Essential Chert, quartz, chalcedony, other rock Minor Zircon, mica, chlorite.	Carbonate(s), iron sulphide, iron oxides, quartz.

Large angular chert grains, some of which have weathered borders, comprise about 45% of the rock. Rounded quartz grains averaging one third the size of the chert grains, make up about 25% of the rock. Little regrowth of the quartz grains has occurred. There are several particles of rock exhibiting an undulatory extinction, which were not identified beyond the fact that they appear to be some type of quartz rock. One such particle contains two small augen-like grains, and has a schistose appearance under plane polarized light. There are a few large angular grains of chalcedony, at least one of which has been enlarged by chalcedonic regrowth in optical continuity with the detrital particle.. A few grains of very fine grained rock are also present. (See slide No. Al-8a).

Zircon is the only abundant minor mineral. One exceptionally fine grain was observed. (Plate 1, No. 5). A few rounded particles of apatite occur scattered throughout the rock.

The chief authigene is carbonate material, which makes up about 15% of the rock. Iron sulphide, probably marcasite, is very abundant. It occurs in one instance as a pebble-like body, in which minute nodules of sulphide are cemented together by carbonate mineral. Several nodules of sulphide have a cryptocrystalline quartz shell, which was apparently crystallized out after the sulphide. Brown iron oxides were also observed. Authigenic quartz is not abundant.

Average Grain Size.

Chert grains, 0.4 to 2.2 mm. diameter.
Quartz grains, 0.4 mm. diameter.
Minor constituents, less than 0.2 mm. diameter.

No. S-4.

Macroscopic Description

A very fine grained gray quartz sandstone, weathering brownish. It contains some carbonate mineral. The fracture is uneven.

Microscopic Description

Composition

Detrital
- Essential
  - Quartz, chert, argillite.
- Minor
  - Zircon, mica, chlorite.

Authigenic
- Quartz, carbonate(s), iron sulphide.

Quartz comprises about 75% of the rock. The grains are uniform in size, and many of them exhibit dust rims, and nearly all have crenulated edges. Rock particles, mainly chert, comprise about 15% of the rock. A few dark brown, banded, angular grains of argillite were observed.

Minor minerals are scarce. Zircon is the most abundant, occuring as rounded grains. Flakes of mica, and chloritic material are disseminated throughout the slide in small amounts.

The chief authigene is quartz, occuring mainly as regrowth around detrital quartz. Carbonate mineral(s) are also abundant, occuring as an interstitial filling. A small amount of iron sulphide was also observed.

Average Grain Size

Quartz, grains, 0,3 mm. diameter.
Rock grains, less then 0.5 mm. diameter.
Minor constituents, less then 0.1 mm. diameter.

M.C. 1. (R.L.R. and J.A.A.)

Macroscopic Description

This rock is a coarse conglomerate containing pebbles of gray and black chert up to one and one half inches in diameter, and a matrix composed dominantly of quartz and chert grains up to one half mm. in diameter.

Microscopic Description

Composition

Detrital
- Essential
  - Quartz, rock particles
- Minor
  - Mica

Authigenic
- Carbonate(s) quartz, iron sulphide

About 50% of the rock is composed of quartz. Quartz grains are of uniform size, and a few of them exhibit some crystal outline, indicating regrowth of quartz. Particles of rock, mainly chert, make up about 30% of the rock. A few chert grains are spherulitic in texture. Argillite grains exhibit good banding, but are not abundant. All rock particles are very angular.

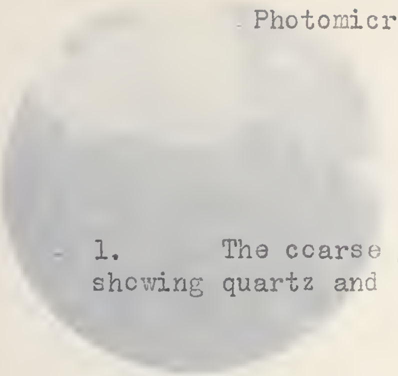
The only minor mineral observed is mica, occuring as minute flakes in the rock particles. None was observed in the matrix.

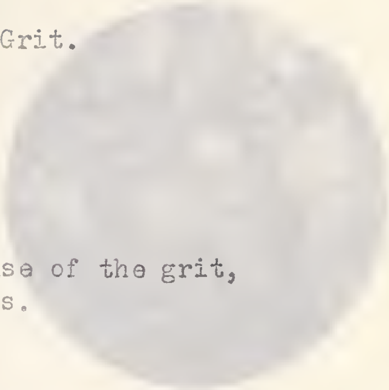
The chief authigenic mineral is carbonate(s), which comprise about 25% of the rock. There is some regrowth of quartz around detrital quartz, and a small amount of iron sulphide was observed.

Average Grain Size

Quartz grains, 0.4 mm. diameter.
Chert grains, 0.5 mm. diameter.

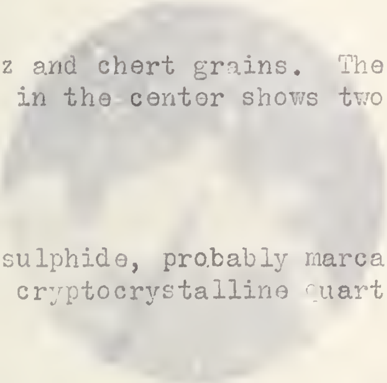
Photomicrographs of Grit.





1. The coarse grained phase of the grit, showing quartz and chert grains.

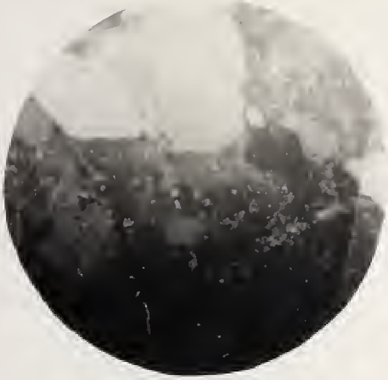
2. The fine grained phase of the grit, showing quartz grains and a few chert grains.



3. Quartz and chert grains. The large quartz grains in the center shows two dust rims.

4. Iron sulphide, probably marcasite, surrounded by cryptocrystalline quartz.

5. Zircon in the coarse phase of the grit.



1.
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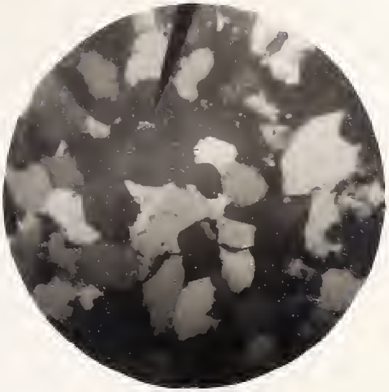

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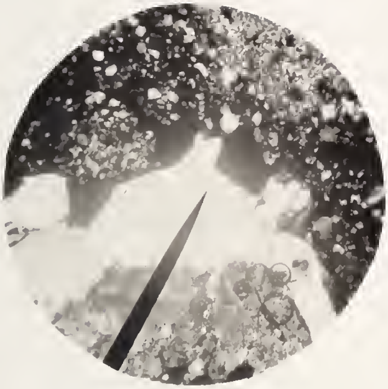

3.
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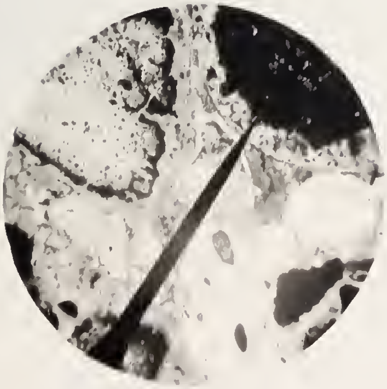
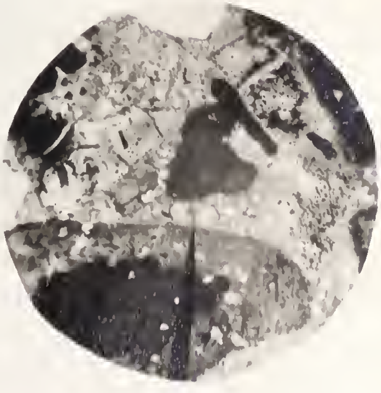


4.
x30



5.
x30

THEORETICAL CONSIDERATIONS

Studies of the grit in the field and in the laboratory lead to certain generalizations which may be made regarding the source, production, and transportation of the sediments, and the probable environment in which they were deposited.

Cretaceous History

The characteristics of any sedimentary deposit are a result of the sedimentary conditions which prevailed during the time the sediments were being deposited. Therefore a brief outline of the Cretaceous history of southwestern Alberta is here included.

Jurassic time closed with a retreat of the sea from the Cordilleran geosyncline. After this retreat a period of erosion and minor deposition took place, and the subaerial or continental sediments of the Kootenay and Blairmore formations were deposited in the present site of the foothills region. The area of deposition probably extended westward to the foot of the Selkirk mountains in southwestern Alberta and southeastern British Columbia.

At the beginning of Colorado time there was some volcanic activity in the southwest part of the province. The Crowsnest Volcanics, of local distribution, but having a maximum thickness of 1,150 feet (MacKenzie, G.S.C. Mus. Bull. No. 4) accumulated as a result of this activity, largely under subaqueous conditions.

During Colorado time the Alberta sea inundated the present foothills and adjacent plains regions of Alberta. This marine invasion began in the Gulf of Mexico area, and the Arctic area at about the same time, and Russell (1939, p. 82) states that the inundation was relatively sudden in southern Alberta. The evidence for this is the fact that "Dark gray marine shales rest sharply upon reddish, plant bearing, supposedly lower Cretaceous shales."

A large embayment of this sea is thought to have extended westward, probably to near the foot of the Selkirk mountains, in southeastern British Columbia.

The Alberta sea did not withdraw from the present foothills region at the end of Colorado time, but extended into early Montana time.

Montana time opened with the Alberta sea still covering the present foothills area. Early in Montana time, however, this sea began to withdraw, rather slowly, and during this period of withdrawal the transition beds between the Upper Alberta Shale and the Belly River were deposited. For the remainder of Montana time deposition in the present foothills area was mainly that of fresh or brackish water. The Bearpaw shales are marine, but they are not always present in the foothills, indicating that the Bearpaw sea did not extend far into the foothill region. Montana time closed with fresh water deposition. The main body of the

Montana sea lay in eastern Alberta and Saskatchewan.

Source of the Sediments

It is essential in considering the possible sources of the Cretaceous sediments in southwestern Alberta, that the general lithology of the sediments be kept clearly in mind. The Cretaceous formations exhibit essentially the same types of sediments, and the same lithological divisions and characteristics, from the Waterton Lakes district north to Bow River.

Schofield (1919, p. 26) considers that certain rocks in the Selkirk mountains were the source of the Cretaceous sediments. He states that "the products of the erosion of these Jurassic mountains are seen in the sedimentation of the Cretaceous of the neighboring Rocky mountains to the east". He draws attention to the fact that the earliest point in the Cretaceous at which conglomerates are found in great amount is at the base of the Blairmore formation, and he considers the chert and quartzite pebbles in them to be derived from the Beltian quartzites in the Selkirks. He mentions pebbles of granite in the upper part of the Blairmore, and interprets them to mean that the Nelson granite batholith, which forms the core of the Selkirk mountains in southern British Columbia, was unroofed and subjected to rapid erosion in late Blairmore time.

Schofield places the uplift of the Selkirks at the end of

Jurassic time. In the following table he presents a hypothetical correlation between events in the Selkirk mountain area and sedimentation in the Rocky mountain area.

Selkirk Mountains	Period	Rocky Mountains
Uplift of Peneplain	Eocene	Orogenic Movements (Laramide Revolution)
Peneplantation to late Maturity (final) Batholith unroofed	Tertiary	Paskapoo-Fresh water sedimentation.
	Upper Cretaceous	Edmonton-Brackish & freshwater. Bearpaw -Marine sedimentation. Belly River-Brackish sedimentation. Colorado-Marine sedimentation. Upper Blairmore-Subaerial sedimentation.
Early maturity Youth (initial)	Lower Cretaceous	Lower Blairmore-Subaerial sedimentation. Kootenay-Subaerial sedimentation.
Possible initiation of Orogenic movements	Upper Jurassic	Marine sedimentation.
Stable marine condition	Devonian and Carboniferous	Marine sedimentation.
Stable marine condition	Lower Palaeozoic	Marine sedimentation.

(Schofield, 1919, p. 28)

P.S. Warren (1938, p. 69) states that "A study of the continental sediments of Cretaceous age in the foothills shows quite definitely that the source of supply of sediments was from the west," and, "this source of supply must have been west of the Rockies---," and "This source of supply could only have been the Selkirk mountains to the west of the Rockies which must have commenced their uplift at this time, i.e. in the Lower Cretaceous."

He points out that in the Crowsnest Pass the Kootenay and Blairmore formations thicken greatly to the west, and contain numerous conglomerates. These formations were infolded with earlier beds in the Rocky Mountain uplift in that area, precluding the possibility of their sediments being derived from the Rockies. Warren's conclusions are apparently largely based upon studies made in the Crowsnest Pass area, and Schofield bases his conclusions on studies made in the southern Selkirk Mountains.

Many geologists working in the Rocky Mountains in the region of the fifty-first parallel however, agree that at least the central and western parts of the Rocky Mountains in that region were high and undergoing erosion in Cretaceous time. If so, it seems reasonable to suppose that the Rocky Mountains were the main source of the Cretaceous sediments.

Daly (1913, pp. 160-161) states that at the end of the Palaeozoic era the sea was largely withdrawn from the Rocky Mountain geosyncline as a result of a broad upwarp, and at least the western half of the geosynclinal belt has been out of water ever since. Erosion probably went forward there in early Mesozoic, and from late Jurassic to the present "both eastern and western belts of the Cordillera have witnessed subaerial erosion".

D.B. Dowling (1922, p. 181) considered that the conglomerates of the Kootenay indicate an early stage in the uplift of the western Rockies, which, he proposed, first appeared in mid-Cretaceous time.

Raymond and Willard (1931, p. 108) studied the Rocky Mountain system along the Canadian Pacific Railway main line. They state that in late Jurassic and early Cretaceous times an uplift affecting the Selkirk and Purcell Mountains occurred, which brought the whole Rocky Mountain area above water.

J.A. Allan has informed the writer that he is of the opinion that the uplift of the Rocky Mountains in the region of the fifty-first parallel, or at least uplift of the central massif of the Rockies, probably commenced in the Late Palaeozoic, and continued all through Mesozoic and early Tertiary time. He considers that the Cretaceous sediments were in large part at least derived from the erosion of the Rockies.

In the foothills between Bow River and the Crowsnest Pass the various Cretaceous formations have essentially constant lithological characteristics. They show no evidence of having a provenance in the region of Bow River different from that in the region of the Crowsnest Pass. Therefore the writer is of the opinion that if the sediments were derived from the Selkirk Mountains in the region of the Crowsnest Pass, then they were probably derived from the same source in the region of Bow River. On the other hand if they were derived from the Rocky Mountains in the region of the Bow River, they were probably also derived from the Rocky Mountains in the region of the Crowsnest Pass. In any case it seems clear from the evidence available at the present time, that the sediments in the Bow River and Crowsnest Pass regions, and between those

regions, were all derived from the same source.

A petrographic study of the grit yielded inconclusive evidence as to the source of the sediments. The chert, argillite, and quartzite grains and pebbles, which are the dominant constituents of the coarser phase, could have been derived from the Precambrian rocks, and early Palaeozoic to a lesser extent, of the Selkirk mountains. These clastics could also have come from the Palaeozoic and early Mesocoic rocks of the Rocky mountains, if they were high. Similarly, the quartz grains could have been derived from rocks in either the Selkirks or the Rocky Mountains.

The following minerals have been identified in the grit by the writer.

Apatite
Biotite
Calcite
Chlorite
Feldspar
Iron oxides
Magnetite
Muscovite
Pyrite and other iron sulphides
Quartz
Siderite
Tourmaline
Zircon

These, and other minerals have been reported (Rice, 1937, pp. 3 - 24) from the Precambrian and early Palaeozoic rocks of the Cranbrook area in the southern Selkirk mountains. The minerals of the Selkirk rocks in the Cranbrook area which are not found in the grit, are, with the exception of sphene and garnet, metastable or unstable species, and might be expected in the grit only in very small amounts if at all. Unfortunately little information is available regarding the composition of the Palaeozoics in the Rocky Mountains. However the minerals identified in the grit

are common in many types of sedimentary rocks, and may reasonably be expected to occur in the Palaeozoic sediments of the Rocky Mountains.

The question of the source of the sediments is, then, unanswered. They apparently came from the west, but whether from the Selkirk Mountains or the Rocky Mountains depends upon the time of the Rocky Mountain uplift. Certain evidence points to the Rockies as the more probable source. The angularity of the coarse clastics suggests short transportation. Furthermore, if the grit was derived from the Selkirk Mountains, it must have been deposited under abnormal sedimentary conditions, and there is no evidence that such abnormal conditions existed, whereas if the grit was derived from the Rocky Mountains, it may be regarded as a normal marine deposit. When the time of the uplift of the Rocky Mountains becomes more definitely known, it may be possible to reach more definite conclusions regarding the source of the Cretaceous sediments in Alberta.

Production of the Sediments

The sediments are thought to have been derived from rocks in the Selkirk or Rocky mountains, both of which areas were likely characterized by fairly high relief. In such areas disintegrative processes such as insolation, frost action, exfoliation, diastrophism, etc. are the dominant sediment producers, and decomposition is at a minimum.

The fact that the grit sediments are mainly clastic, relatively clean, and lacking in decomposition products suggests that decomposition was of secondary importance. Decomposition products could have been sorted out in transit, but if they were present in an important amount, they might be expected in more abundance in the sediments examined. The paucity of unstable minerals in the grit might suggest decomposition at the source, with consequent removal of the unstable species. Two alternative explanations of this condition are possible.

(a) Unstable minerals were not abundant in the source rocks. This is known to **be** true of certain rocks in the southern Selkirk Mountains, but the mineral content of the rocks in the Rocky Mountains is not known.

(b) As pointed out by Bramlette (1941, p. 36) unstable minerals may be leached out of sediments after deposition, and even after lithification.

The writer believes, in view of these considerations, that the sediments of the grit were largely produced by the processes of disintegration.

Transportation of the Sediments

Regarding the transportation of the Cretaceous sediments, Schofield (1920, p. 90) states that, "The products of this erosion of the eastern highland were carried by rivers and in part deposited in the great geosynclinal which occupied the site of the present

Rocky Mountains, and the Great Plains, where they may be seen at present." He also advanced the suggestion that the ancestors of the streams which now flow eastward through the Yellowhead, Kicking Horse, and Crowsnest passes were present in Cretaceous time. His remarks are based on the assumption that the sediments were derived from the Selkirk Mountains.

Schofield is probably correct in believing the transportation to have been mainly accomplished by streams, whatever the source, but there are no indications in the Cretaceous sediments of the presence of the three specific ancestral streams which he suggests. Whether the transportation was accomplished by a few large, or many small streams is difficult to say. Regarding the Cretaceous of Western Montana and Wyoming, Twenhofel (1939, p. 106) has stated that the sediments are probably delta deposits, made by rivers flowing from the west. Such may also be true in Alberta, and if so, the probability is that the rivers were fairly large.

The sediments of the grit were probably not transported a very long distance. If the Alberta sea lay against the eastern and southeastern slopes of the Rocky Mountains the sediments of the grit could have been derived from the shore rocks by wave and current action, with a small amount being added from the streams flowing into the sea. In this case, although the total transportation undergone could be long, the sediments would probably never be very far removed from the source. On the other

hand, the sediments could have been carried to the sea by streams from a short distance back of the shore. In either case, short transportation is indicated by the angularity of the coarse grains.

The degree of rounding exhibited by the clastics of the finer phases could have been accomplished, even from strong angularity, by the action of waves and currents of the littoral and neritic zones, after the sediments were deposited in the Alberta Sea. The coarse clastics would be less effected by such wave and current action than the fine clastics and would therefore retain a greater degree of angularity.

If the sediments were derived from rocks in the Selkirk Mountains, they were likely largely transported by streams to the Alberta sea. In the Crowsnest Pass region, where the embayment of the Alberta sea extended into southeastern British Columbia, transportation may have been slightly shorter than in the Bow River region.

The Environment of Deposition

Marine conglomerates are the consolidated gravels of the littoral and neritic zones. Deposition of gravels on bathyal bottoms probably only occurs where bathyal depths are near shore.

The main sources of the sediments of marine gravels are the shores. The shores and lands adjacent to the shores, are probably high and poorly vegetated, thus limiting mature de-

composition, and they must be composed of rock of a type that could provide particles of gravel dimension. The sediments are largely produced by wave and current action, both of which require deep water for development of sufficient strength to acquire gravels from the shores.

Marine gravels probably do not attain thicknesses of much over twenty feet on littoral bottoms, whère such gravels have their maximum development. The lateral distribution of marine gravels depends upon the quantities of sediments available and the carrying power of the waves and currents affecting them. Twenhofel (1936, p. 689) considers that marine gravels would not commonly be transported to distances greater than ten or perhaps fifteen miles from shore. The gravel units of the littoral zone are wedge shaped, and they thicken shorewards.

Some marine conglomerates are associated with unconformities, but marine gravels cannot be considered as infallible criteria of unconformities.

Twenhofel, (1935, p. 680 - 684) considers that marine conglomerates may be deposited under three conditions of sea level.

(A) Under conditions of stationary sea level.
(B) Under conditions of rising sea level.
(C) Under conditions of falling sea level.

A deposit exhibiting the characteristics of the grit could most readily have been developed under conditions of

stationary sea level.

Assuming that the sediments of the grit were derived from the Rocky Mountains; that the shore line of the Alberta sea extended in a north and south direction, parallel to the region where the grit was studied in the field; and that the sediments were deposited upon the neritic bottom, the writer suggests that the sequence of events resulting in the deposition of the grit may have been as follows: In the early stages the shore line of the sea was advancing to the west, i.e. sea level was rising, and black sandy shales were deposited as shown in Figure 3. A pause in the advance of the shore line occurred and sea level was for a brief time stationary. Under such a condition the shore lands were above the base level of erosion, and the neritic bottom was below the base level of deposition. As the sea eroded away the shore, for example from B to B', a wave and current cut rock floor A'B', not necessarily consolidated, was produced. This floor was at base level of erosion and base level of deposition. The sediments resulting from this erosion of the shore, with the exception of the coarsest which migrated with the beach, were carried seaward across the wave and current cut floor, and deposited on the neritic bottom DA'. The neritic bottom thus received sediments and was built up towards base level of deposition. This level, if reached, would be attained first at A', the upper edge of the neritic zone, and last at D, the upper edge of the bathyal zone, and therefore the sediments were carried

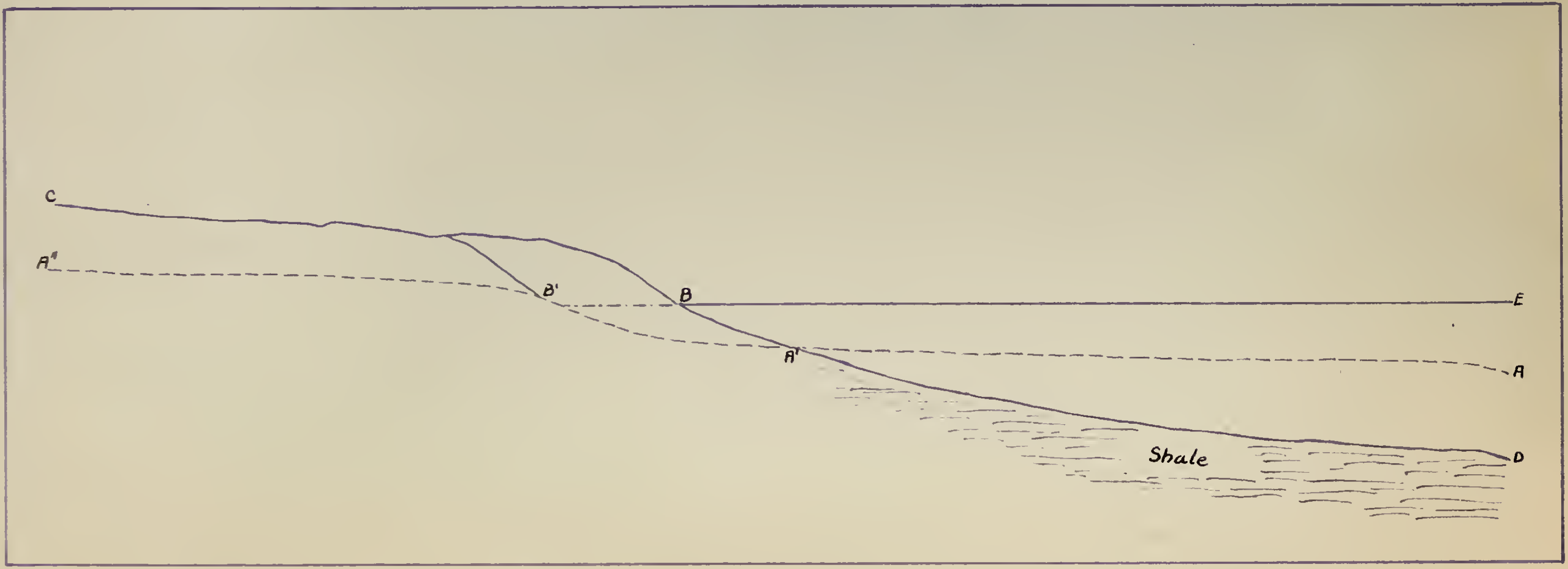


Fig. 3

BE = Sea Level
A"A' = B. L. of Erosion
A'A = B. L. of Deposition
B'A' = Rock Floor
CB = Shore Profile
BD = Neritic Bottom

progressively farther out to sea. The result was an irregular lens shaped deposit of increasing coarseness from bottom to top. A rise in sea level or subsidence of the shore land, resulted in the deposition of finer sediments, i.e. shales, over the previous deposits of the neritic bottom, i.e. over the neritic gravels. If the shore was eroded back to the point B' before this rise in sea level occurred, erosion then ceased since the shore line had reached base level of erosion. Thus if and when the point B' was reached, a period of non deposition began, and the upper surface of the neritic gravel represents a disconformity.

Thus if the Alberta sea paused as it advanced in early Colorado time, with its western shore against the foot of the Rocky Mountains, a zone of sediments like the grit could have been deposited. The increasing coarseness from bottom to top exhibited by the grit zone, and the apparent lens shape of the grit deposit, are characteristics that would normally be developed in sediments deposited under conditions as outlined above. The apparent thickening of the grit southwards may be explained as due to bottom irregularity. However there are certain questions which this hypothesis leaves unanswered. It does not explain why the thickness of Lower Alberta Shale beneath the grit increases to the west, nor does it explain the fact that the grit is sharply divided into a fine grained lower phase and a coarser upper phase, instead of exhibiting a gradual increase in coarseness from bottom to top.

Finally, it does not explain the increasing coarseness of the grit southward.

Whether the upper surface of the grit represents a disconformity the writer is not prepared to say, since according to the hypothesis that has been advanced, any rise in sea level before the shore was cut down to base level of erosion would have resulted in continuous deposition, and therefore conformable relations between the grit and the overlying beds. The upper surface of the grit represents a disconformity only if sea level remained stationary for a sufficiently long time for the shore to be eroded to base level.

It seems improbable that the grit was deposited under conditions of a temporarily falling sea level, since the sediments would have been reworked as sea level subsequently rose, and would have the characteristics of sediments deposited under conditions of rising sea level. If the grit had been deposited under conditions of rising sea level, the zone would normally be progressively finer from bottom to top, and since the grit exhibited a decided increase in coarseness from bottom to top at all exposures observed, it appears improbable that it was deposited under such conditions.

It is unlikely that the grit is a littoral deposit. This is indicated by the fact that the zone apparently thins shoreward, i.e. to the west, a condition normally incompatible with the littoral environment. Furthermore, the known width of the grit deposits is much greater than the normal width of a littoral

zone. In this report however, it must be kept in mind that very wide littoral zones are known at the present time in some areas.

If the grit were derived from the Selkirk mountains, very abnormal conditions would be required to account for the accumulation of the sediments so far from the source. An extremely wide littoral zone and wave cut rock floor might have placed the neritic zone far enough east of the Selkirks to allow accumulation of a marine gravel in the region where the grit is known, but there is no evidence that such a wide littoral zone and rock floor existed.

Conclusions Regarding Source, Transportation and Deposition

Hard and fast conclusions cannot be drawn regarding the provenance, transportation, and deposition of the grit sediments, but the writer, on the basis of the available evidence, both factual and theoretical, has come to certain tentative conclusions. The sediments of the grit were derived from the west, probably from the Rocky Mountains, largely by physical processes. They have undergone short transportation, perhaps partly by streams, but probably by waves and currents in the Alberta sea as well. The sediments were deposited in the neritic zone of the Alberta sea under conditions of a temporarily stationary sea level, which was followed by a rise in sea level.

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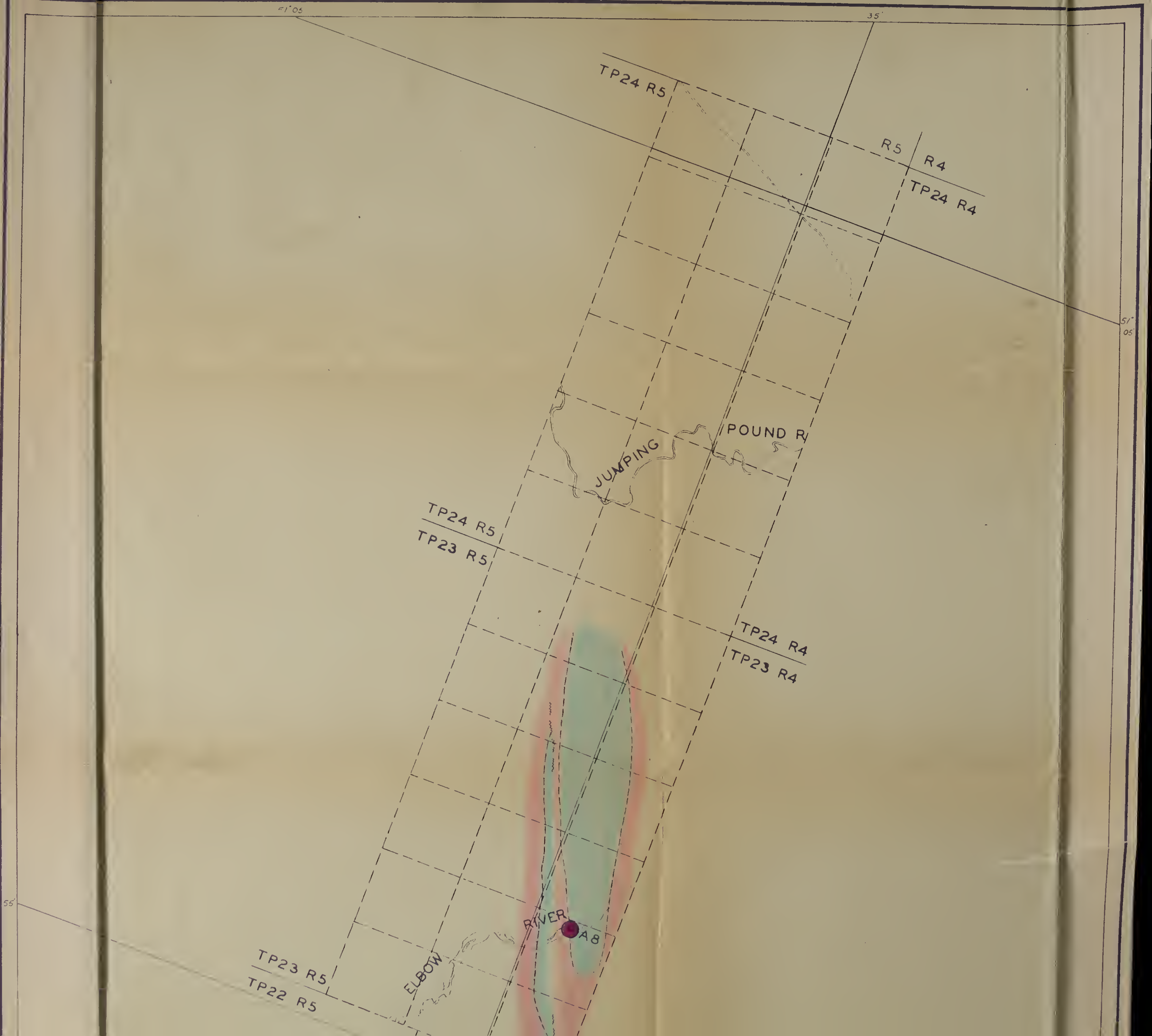
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35'
TP24 R5
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R4
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JUMPING
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51°
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RIVER
A8
ELBOW
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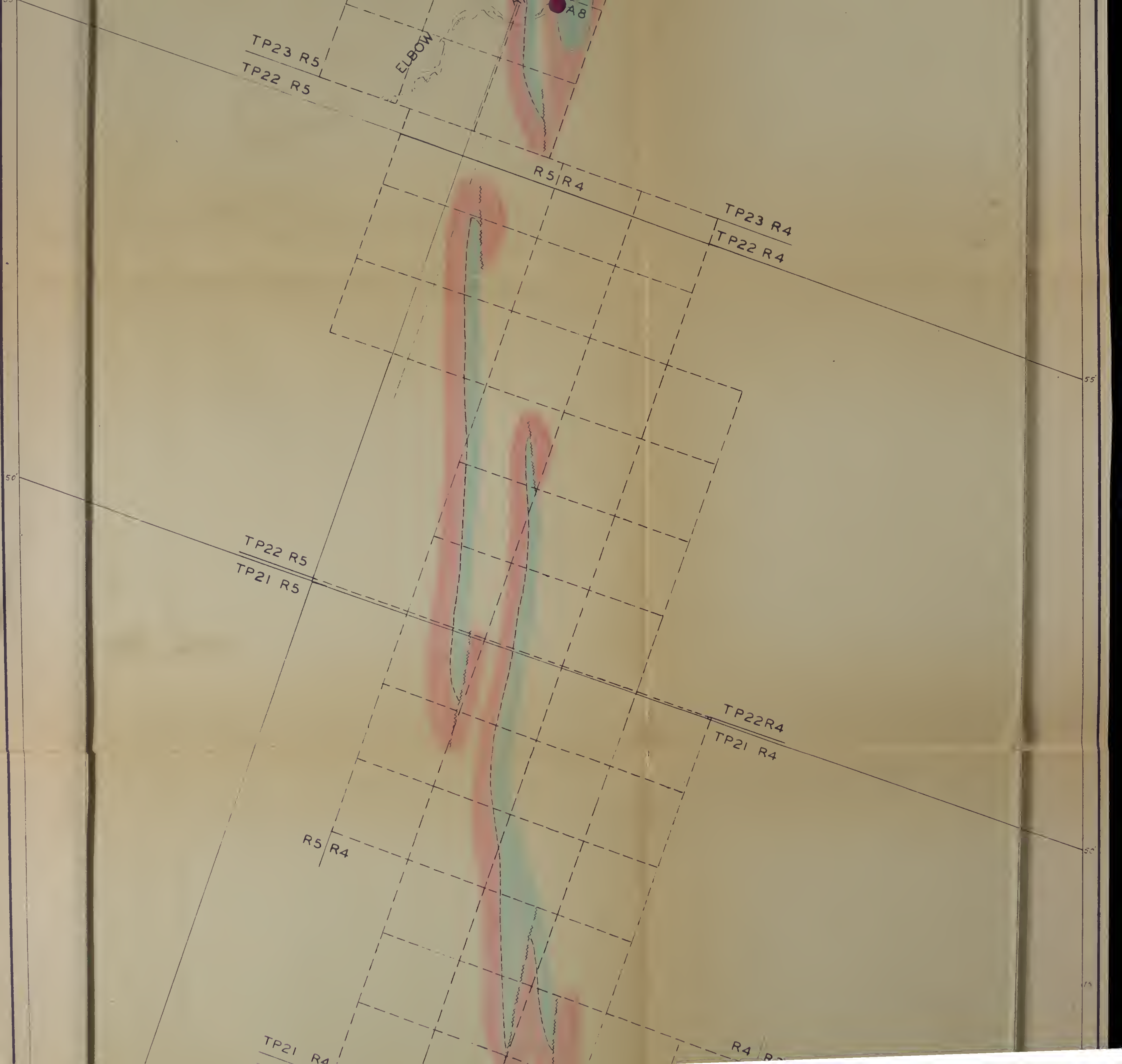
TP22 R5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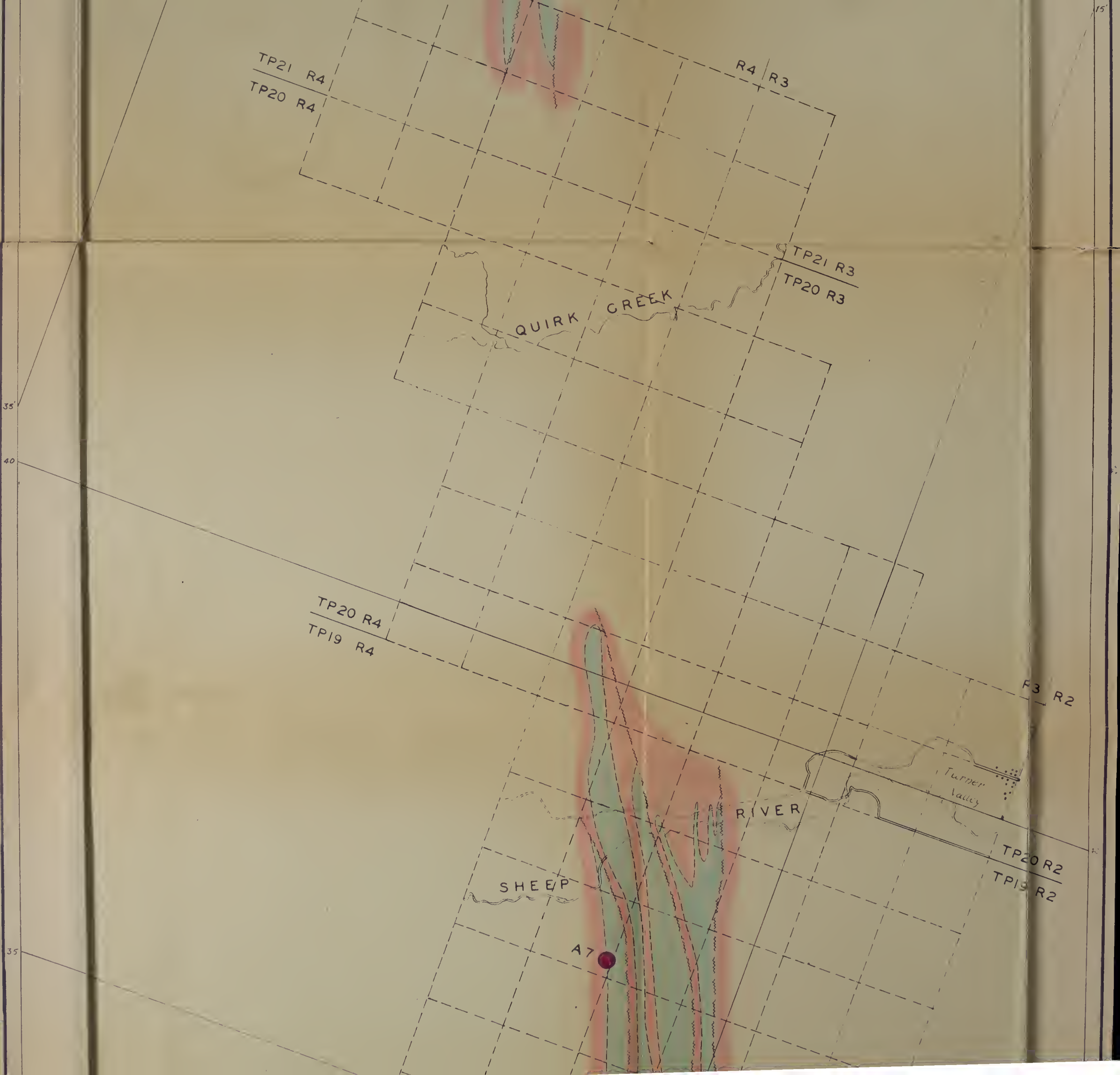

15'
TP21 R4
TP20 R4
R4 R3
TP21 R3
TP20 R3
QUIRK CREEK
35'
40
TP20 R4
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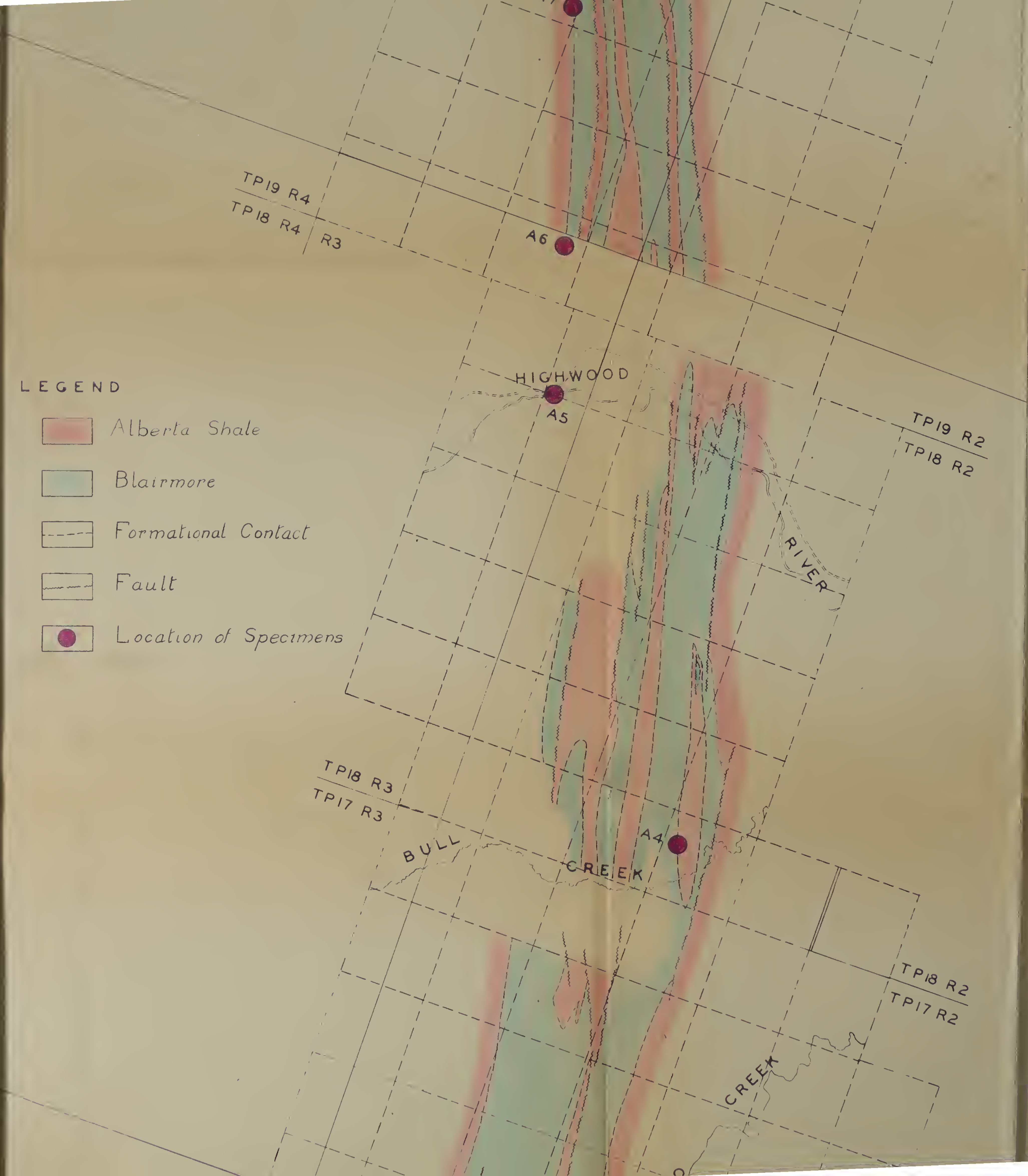
R3 R2
Turner Valley
RIVER
TP20 R2
TP19 R2
SHEEP
35
A7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Alberta Shale
Blairmore
Formational Contact
Fault
Location of Specimens
TP19 R4
TP18 R4
R3
A6
HIGHWOOD
A5
RIVER
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BULL
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CREEK
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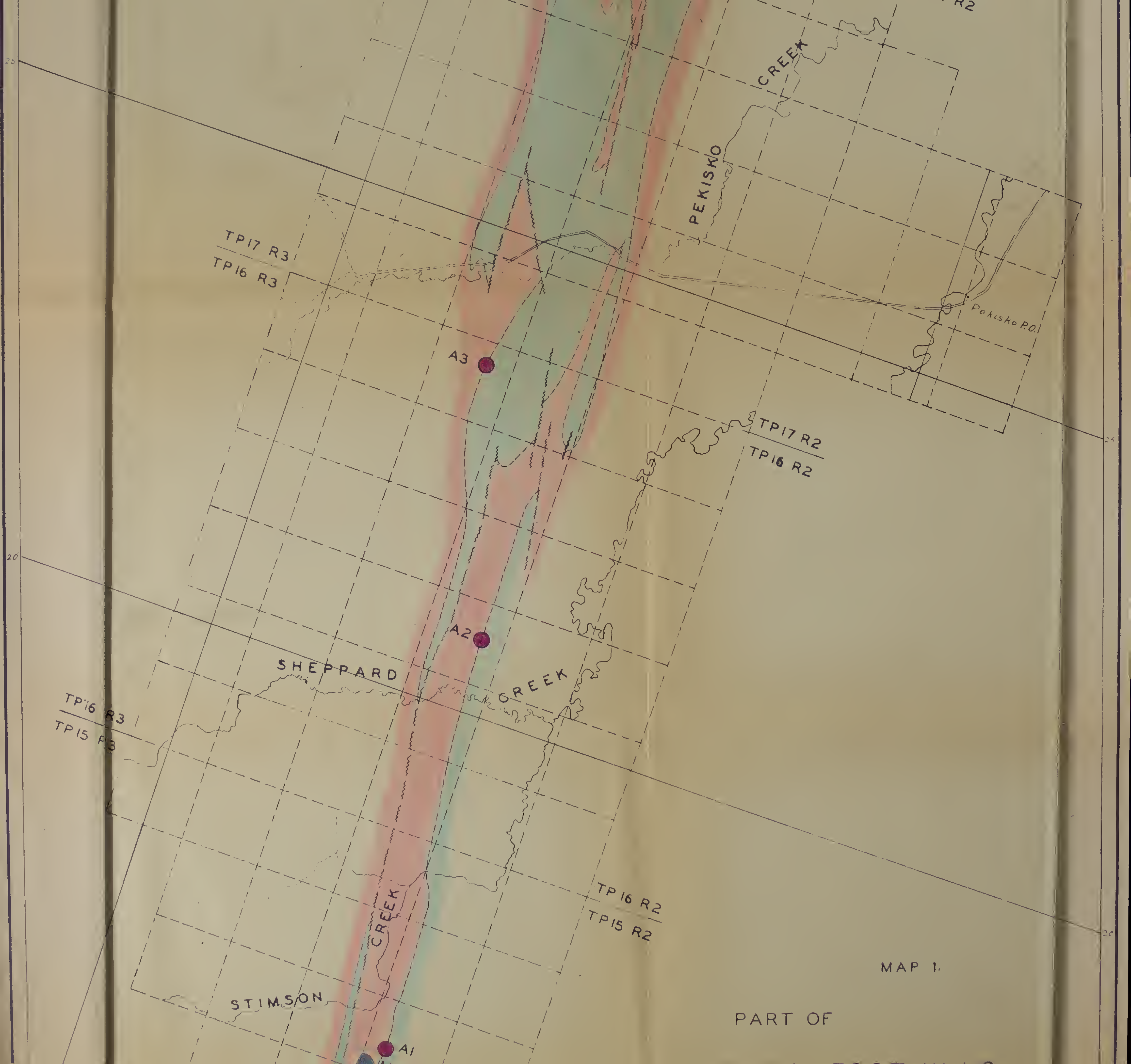
R2
PEKISKO CREEK
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A3
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CREEK
STIMSON
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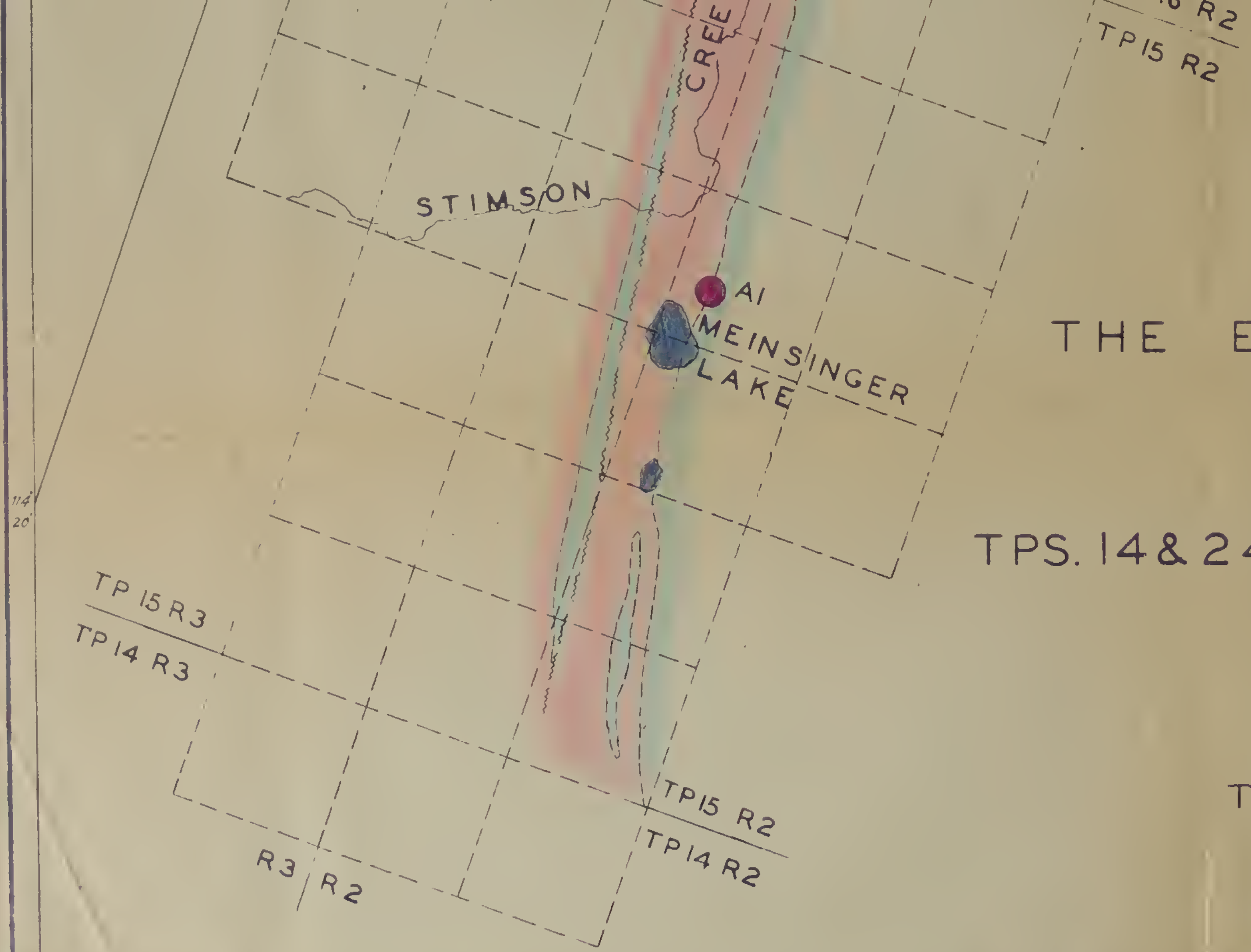
25
20

MAP 1.

PART OF



MAP 1.

PART OF
THE EASTERN FOOTHILLS
BETWEEN
TPS. 14 & 24, RANGES 2 TO 4, W5 MER.,
ALBERTA.

TO ACCOMPANY THESIS
by
F. G. FOX.

Scale: 1 inch = 1 mile *1942.*

B29749